Bean/Cowpea CRSP
WEST AFRICA REGIONAL WORKPLAN/ANNUAL PROGRESS REPORT
October 1, 2000-September 30, 2001

I. REGIONAL PROJECT WORKPLAN/ANNUAL PROGRESS REPORT FOR FY 2001

I.A. Constraint #1: Insufficient Production/Natural Resource Management Techniques

I.A.1. Research area: Develop and apply improved breeding and transformation methods

I.A.1.a. Background: Few resources have been targeted to cowpea breeding and transformation methods in relation to the crops importance worldwide. An efficient transformation system would open the possibility of incorporating trans-genes for insect pest resistance and other useful traits. The genetic map of cowpea is not yet sufficiently dense to employ effective DNA marker-assisted selection. New mapping technologies can be used to rapidly discover new markers. Identification and incorporation of insect resistance has been problematic for many pests due to insufficient screening for genetic variation and low heritability of the resistance. Sources of strong resistance need to be sought, as well as improved methods to incorporate this resistance into useful varieties, including genetic transformation. Heat tolerance has been shown to be effective in increasing yields in California but different screening procedures are needed for use in Africa. There is also a need to elucidate and incorporate traits important to performance in different cropping systems. Impact of any specific new trait at the farm level will require development of cultivars that have a complete package of available pest and disease resistances, stable performance, and seed quality traits preferred by farmers and consumers in individual regions targeted by the West African Regional Project.

I.A.1.b. Proposed research area workplan and subsequent annual progress report

I.A.1.b.(1) Activity #1: Genetic mapping of cowpea
I.A.1.b.(1)(a) Priority: (1) Essential
I.A.1.b.(1)(b) U.S. researchers: Murdock, Hall, Ehlers, Roberts
I.A.1.b.(1)(c) HC researchers: Ousmane, Cisse
I.A.1.b.(1)(d) Methodology: Physiological and morphological traits would be added to the existing genetic map of cowpea by screening the UCR mapping population of 94 RIL's developed from a cross between IT84S-2049 and 524B for traits for which the parents differ. Molecular markers (AFLPs, SSRs, etc.) would be mapped using the above 94 RIL's and for a population segregating for Striga resistance at Purdue, and for a population (IT83D-1137 x 58-57) segregating for Striga, bacterial blight, cowpea aphid-borne mosaic virus, and bruchid resistance at ISRA. An updated second version of the CRSP cowpea genetic linkage map would be developed.
I.A.1.b.(1)(e) Anticipated (1 year) results of activity: Mapping of useful genetic traits and increased density of molecular markers and publication of the second version of the CRSP cowpea genetic linkage map.

I.A.1.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Development of effective marker assisted selection protocols result in more rapid development of improved varieties, and potentially, gene cloning of useful traits	Five years	Use of marker assisted selection protocols by cowpea breeders

I.A.1.b.(1)(g) Budget:

IRAD	$ 3,000
ISRA	2,000
Purdue (Murdock)	7,000
UCR	2,000
Total (Direct costs only)	$14,000

1.A.1.b (1)(h) Major changes: None

1.A.1.b.(1)(i) Progress during past year UCR, California**:** An updated second version of the CRSP cowpea genetic linkage map was developed (Figs. 1 and 2) that is described in the following publication. Ouédraogo, J. T., B. S. Gowda, M. Jean, T. J. Close, J. D. Ehlers, A. E. Hall, A. G. Gillaspie, P. A. Roberts, A. M. Ismail, G. Bruening, P. Gepts, M. P. Timko and F. J. Belzile. An Improved genetic linkage map for cowpea (*Vigna unguiculata* L.) combining AFLP, RFLP, RAPD and biological markers and biological resistance traits. Genome (accepted August 1, 2001).

The map is based on the recombinant inbred line cowpea population developed by the CRSP project of Tony Hall at UCR. Jeremy Ouédraogo who was a Ph.D. student from Burkina Faso supervised by Professor Francois Belzile at the University of Laval, Canada and Professor Mike Timko, University of Virginia developed and scored a set of 242 AFLP markers that were added to the 181 RAPD, RFLP, AFLP and biochemical markers previously mapped by the group of Paul Gepts at UC, Davis, Tony Hall at UCR and Ph.D. student Cristina Menéndez. In addition, 18 biological resistance/tolerance traits, resistance genes and resistance gene analogs were scored and mapped. These included: resistance to *Striga gesnerioides* races 1 and 3 (M. P. Timko), Fusarium wilt race 3 (J. D. Ehlers and A. E. Hall), root knot nematode (J. D. Ehlers, P. A. Roberts and A. E. Hall) and several viruses (CPMV and CPSMV by G. Bruening and BlCMV and SBMV by A. G. Gillaspie), and the phenotypic expression and structural gene of a dehydrin protein that confers chilling tolerance at emergence in cowpea (A. M. Ismail, A. E. Hall and T. J. Close).

The updated map of cowpea consists of 11 linkage groups spanning a total of 2670 cM, with an average distance of 6.43 cM between markers.

ISRA, Sénégal: A set of 120 F_6 recombinant inbred lines (RILs) has been developed between Mouride and Bambey 21. A cooperating organization in Sénégal, CERAAS (Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse) is screening the parents to detect DNA polymorphisms and would screen the RILs for them. ISRA would screen the RILs for biological traits. The objective is to discover QTL's or markers for drought adaptation, biological nitrogen fixation and resistance to Striga.

IRAD, Cameroon/Purdue: An F_2 population of a cross involving a parent resistant to all five races of *Striga gesnerioides* (IT93K-693-2) with a susceptible parent (IT93K-452-2) was

developed at IITA's Kano station, Nigeria. During the summer of 2000, this population was screened and leaf samples collected for DNA analysis. Unfortunately, only partial leaf samples could be collected due to the unexpected dryness of the plants. Subsequently, remnant seeds of this population were planted in the summer of 2001. During Ousmane Boukar's recent visit to Kano (September, 2001) the plants were again found to have matured unexpectedly early, and no leaf samples were collected. In both 2000 and 2001 seasons, the expected genetic segregation ratio of 3:1 for *Striga* resistance was not observed. Discussions with Dr. B.B. Singh revolved around the hypothesis that the existence of a single *Striga* resistance allele (other than that prevailing in Nigeria) in the "susceptible" parent and /or the early maturity of the two parents are possible explanations of the unanticipated early maturity and unexpected segregation ratios. For the molecular marker study, screening of F_3 seeds will allow confirmation of the resistance of some F_2 plants and bulk segregant analysis. This approach will provide an opportunity to correct the partial screening of the F_2's and to speed up the study. This year, a series of near isogenic lines are being screened for *Striga* resistance and the results may be incorporated in the study.
1.A.1.b.(1)(j) Current status of research: Beginning in the late 1980's, Tony Hall at UCR developed a set of recombinant inbred lines from a cross between two cultivated cowpeas that was then used in a collaborative effort with Paul Gepts at UC Davis to develop the first DNA linkage map of cowpea based on domesticated lines that was published in 1997. The numerous markers and biological traits on the updated second version in the 2001 map will facilitate the development of marker-assisted selection protocols that could enhance the efficiency of cowpea breeding and the map-based cloning of the resistance genes to facilitate their exploitation by genetic engineering.
1.A.1.b.(1)(k) Documented impact: No impact yet on the general public. The project has partially contributed to the Ph.D. training of a host country scientist in the molecular biology skills needed to develop and use DNA markers in cowpea breeding. Dr. J. T. Ouédraogo obtained his Ph.D. from the University of Laval in a program using non-CRSP funds but the cowpea genetic lines developed by the CRSP at UCR provided a foundation for his study. He has now returned to Burkina Faso and is a potential collaborator for the next phase of the CRSP.

I.A.1.b.(2) Activity #2: Develop an efficient transformation method
I.A.1.b.(2)(a) Priority: (1) Essential
I.A.1.b.(2)(b) U.S. researchers: Murdock, Bressan (Purdue)
I.A.1.b.(2)(c) HC researchers:
I.A.1.b.(2)(d) Methodology: The Purdue group will be evaluating the current low-efficiency methodology being used at IITA, and seek ways to improve it. This will involve a large number of attempts at increasing efficiency, including (1) testing a variety of cowpea accessions with different geographic origins in the hope of finding one with optimal transformability (2) using the latest available Agrobacterium vectors (3) markedly increasing the selection pressure on candidate transformed materials so as to eliminate large numbers of false positives (4) experimenting with growth media (e.g., plant hormone concentrations) to optimize regeneration of plants.
I.A.1.b.(2)(e) Anticipated (1 year) results of activity: Within the fiscal year, we should be closer to an efficient transformation method based upon better selection of starting genotypes, culture conditions and Agrobacterium vectors. The goal is to reach a transformation efficiency of 0.5 to 1.0 percent.

I.A.1.b.(2)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Transgenic cowpeas with potential for incorporating many traits, especially Bt and alpha-amylase genes for insect resistance	A substantially improved and practically useful cowpea transformation system should be attainable within the time remaining for the current extension of the CRSP	Incorporation of BT and/or alpha amylase inhibitor genes

I.A.1.b.(2)(g) Budget:

Purdue (Murdock) $35,000
Total (Direct costs only) $35,000

I.A.1.b.(2)(h) Major changes: see below

I.A.1.b.(2)(i) Progress during past year: We can report no technical progress from laboratory studies during the past year. The relaunch of work on cowpea transformation was delayed until after the Dakar meeting on cowpea genetic improvement in January, 2001. At the meeting, a detailed plan was developed which would have had Jesse Machuka, formerly of IITA, coming to Purdue to work on cowpea transformation for several months and then to continue the work on cowpea transformation for several months with T. J. Higgins. Unfortunately, Machuka returned to Kenya to seek new employment and was not able to follow through with these plans. An alternative strategy has been developed to hire a post-doctoral researcher with outstanding experience and success in plant transformation to pursue this work during the final seven months of the project.

The hiatus in our transformation research is the result of a series of strategic developments for cowpea biotechnology led by Larry Murdock during the year. In brief, Murdock organized an international conference on the genetic improvement of cowpea held in Dakar, Senegal, on January 8-12, 2001. Support for the conference was from the Rockefeller Foundation, the Bean/Cowpea CRSP, FAO, IITA, Purdue University, and ISRA-Senegal. The purposes of the meeting were: (1) to review the "state-of-the-art" in regards to genetic improvement of cowpeas and (2) develop a set of coordinated workplans addressing ALL of the prospective constraints impeding the eventual development and deployment of genetically-improved (including transgenic) cowpeas. Experience with other crops important in developing nations has proven that uncoordinated efforts to transform and deploy a transgenic crop are plagued by stops and starts, intellectual property roadblocks, lack of public information, biosafety issues, poor communications, and much more. Avoiding this gave impetus for the Dakar meeting. Constraint areas addressed in Dakar included: (1) genetic transformation (2) the policy framework and intellectual property rights (3) public information (4) trade, marketing and economics (5) genetic mapping and tools for breeders (6) food and environmental safety issues (7) breeding, seed supply and commercialization. The meeting was attended by 48 scientists and administrators, the majority of whom were from nine African countries. The chief results of the meeting are incorporated in the Symposium/Workshop report, which is available to anyone interested.

The Purdue group did not initiate work on cowpea transformation prior to the Dakar meeting because we felt that to do so in the absence of discussions with all of the experts involved in or interested in cowpea transformation would likely have been wasteful: IITA sent Jesse Machuka, who had been involved in transformation attempts in IITA's biotechnology laboratory in Ibadan. One of the world's experts on legume transformation, T. J. Higgins, was also present and made a commitment to work on cowpea. Idah Sithole-Niang of Zimbabwe, and Richard Alison of Michigan State University, who are working collaboratively on an electrical cowpea transformation system were both in attendance. The CRSP's Doug Maxwell, whose results with common bean have been promising, also participated. One of the purposes of the meeting was to develop a coordinated plan for cowpea transformation. Such a plan was developed. It included several elements: 1) Idah Sithole-Niang would continue her work on electrical transformation of cowpea in collaboration with Richard Alison; 2) T. J. Higgins would develop a cowpea transformation proposal and submit it to the Rockefeller Foundation; 3) Purdue would coordinate its work with the Higgins project (Higgins had already successfully transformed garden pea, and his transformed lines had resistance to pea weevil and was being field tested in Australia), as follows: Purdue would initiate work to identify an optimal Bt gene suitable for Maruca vitrata – we already knew that Bt's are effective against Maruca, but the transformation group agreed that it was important to survey a broader range of Bt's so as to identify an optimally active form; 4) Linkages with the IITA group, whose transformation work was in flux, would be established so as to ensure coordination; 5) Once an optimally-active Bt protein was identified, Purdue would take responsibility to develop an appropriate transformation vector construction that could be used at Purdue and in Australia to transform cowpea; and 6) In Dakar, Jesse Machuka, still with the IITA, indicated his intention to leave IITA, but expressed a desire to continue to work on cowpea transformation in another capacity.

A plan was developed whereby Machuka would come to Purdue in the summer of 2001 to work with Ray Bressan and carry out two work elements: (a) to evaluate a range of cowpea genotypes for regeneration in the hope of finding an easily transformable type and (b) begin constructing the Bt-containing transformation vector. Thereafter, he would go to Australia to work on cowpea transformation under the direction of T. J. Higgins. The intended result of this plan, to which everyone in the Transformation Constraint group concurred, was a coordinated effort to transform cowpea involving all laboratories known to have an active interest in cowpea transformation. It was agreed that multiple efforts at transformation should continue in as many laboratories as possible. Any breakthrough in one laboratory would result in a reallocation of resources in the various laboratories to exploit the breakthrough as rapidly as possible.

Unfortunately, several factors delayed the implementation of the plan. There was a delay of several months in the submission of a proposal to the Rockefeller Foundation by T. J. Higgins, due to his accepting a temporary but major administrative responsibility in his organization, C.S.I.R.O. There was also a long delay in obtaining permission from USDA's APHIS to import and rear Maruca vitrata at Purdue. The necessary import permit was only received near the end of the 2001 FY, so work could not begin in time to report any results. Jesse Machuka, who had returned to Kenya to seek employment there, was not able to follow through on his plan to come to Purdue and subsequently, Australia. Finally, the Rockefeller Foundation has, to date, not determined if it would fund T. J. Higgins studies of cowpea transformation.

Currently, the Purdue group has devised an alternative plan to hire an postdoctoral expert in plant transformation to work on cowpea, and has begun the process of obtaining Maruca eggs to carry out the needed bioassays of Bt's. Purdue also has been working with Monsanto Company with the goal of obtaining a series of Pyralid-active Bt's to test against Maruca. We also have been conducting a campaign to obtain the needed intellectual property for cowpea transformation such that credit is given to IP donors while protecting them from liability but also ensuring that the users of donated intellectual property retain freedom to operate.
Thanks to the work of Jess Lowenberg-DeBoer, crop maps and crop calendars have been

developed for cowpea which will be used to persuade potential donors of intellectual property that any donations will not result in any conflicts with the companies business interests.

We regret that we do not have technical progress to report, but at the same time we hope it is clear that we have not been idle in the cause of creating a comprehensive plan that is essential for practical and useful cowpea transformation – practical and useful meaning that the products of the work can eventually reach the growers of cowpea in Africa.

Most of the funds allocated for the research were returned to the MO for reallocation. A small part of these monies were used to cover one-time close-out costs in Cameroon that had not been budgeted, and as supplementary support for the Dakar cowpea meeting.

I.A.1.b.(2)(j) Current status of research: The next steps are to hire a postdoctoral associate with expertise in plant transformation, a probable hire with the requisite experience has been identified. We are also initiating work to obtain and screen a selection of pyralid-active Bt's in feeding bioassays at Purdue with the intention of (1) identifying an optimal Bt form and (2) verifying that it is effective against a range of Maruca ecotypes. The Purdue team participated in a USAID-sponsored cowpea biotechnology coordination meeting in Washington, D.C. on October 29, 2001. Purpose of the meeting was to ensure that major participants in cowpea biotechnology work are in good contact and reinforce one another in their work and keep open communication lines.

I.A.1.b.(2)(k) Documented impact: The Purdue CRSP team has asserted leadership in creating a comprehensive approach to cowpea biotechnology, with encouragement from numerous organizations including the Rockefeller Foundation, IITA, FAO and others. The NGICA community, which grew out of the Dakar meeting, is a real embodiment of an international, multidisciplinary effort to bring the tools of biotechnology to bear on the genetic improvement of cowpea, and has already produced and submitted multiple proposals to access needed funds in various research areas. Without the commitment of the Bean/Cowpea CRSP to cowpea transformation, the Dakar meeting and numerous other initiatives would never have occurred. Actual available documentation would include the Dakar meeting report, various grant proposals, and evidence of initiatives with major biotechnology companies.

I.A.1.b.(3) Activity #3: Develop cowpea germplasm with specific adaptation to the Sahel, the wet and dry Savannah zones of Africa and to the U.S.

I.A.1.b.(3)(a) Priority: (1) Essential

I.A.1.b.(3)(b) U.S. researchers: Hall, Ehlers

I.A.1.b.(3)(c) HC researchers: Cisse, Wade, Denwar, Ousmane and Ntoukam

I.A.1.b.(3)(d) Methodology: Use pedigree, bulk, and backcross breeding procedures to develop germplasm and agro-ecosystem-based ideotypes with packages of resistance traits such as resistance to Striga, ashy stem blight, bacterial blight, root-knot nematodes, Fusarium wilt, potyviruses, lygus, cowpea aphid, flower thrips, pod bugs, hairy caterpillar and bruchids, drought adaptation through earliness and delayed leaf senescence (DLS), heat tolerance and plant growth habit traits that confer adaptation to the major agro-ecologies being served by the CRSP. Selection criteria will also include specific regional grain quality preferences. Screening for specific traits will be done in specific countries where the most effective screening nurseries for traits can be developed with transfer of selected and more advanced germplasm to collaborators in other countries. At SARI in Ghana, preliminary and advanced breeding lines and varieties will be screened for resistance to Striga, flower thrips, pod sucking bugs and diseases. Most of this material is from the Ghana breeding program, some

material is from the CRSP projects in Senegal, Cameroon and UCR, and some is from IITA. The most promising materials will be performance tested at four sites that are representative of the four major agro-ecological zones of northern Ghana. In Senegal, station and on-farm trials will conducted with new advanced breeding lines including a red grained type (819). Selection of lines with large Mougne type grain will continue. Lines will be screened for striga resistance. In California, preliminary and advanced breeding lines will be screened for resistance to root-knot nematodes, Fusarium wilt, cowpea aphid, lygus bug, heat tolerance and DLS. The most promising materials will be performance tested at three sites in California. Lines developed by UCR/Senegal with earliness from Melakh, pest resistance from Mouride and DLS from UCD8517 will be evaluated in Bambey, Senegal and by SARI, Ghana.
I.A.1.b.(3)(e) Anticipated (1 year) results of activity: Breeding lines will be developed with resistance to several pests, diseases and stresses, other adaptive traits and appropriate grain quality for different zones.
I.A.1.b.(3)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Cowpea varieties with superior, yield, yield stability and grain quality adapted to major zones being served by the CRSP	Five years	Release and adoption of new cowpea varieties

I.A.1.b.(3)(g) Budget:

IRAD	$ 4,000
SARI	3,218
ISRA	14,500
UCR	17,500
Total (Direct costs only)	$39,218

1.A.1.b.(3)(h) Major changes: None
1.A.1.b.(3)(i) Progress during past year ISRA, Sénégal Trials: A potential new cowpea variety has been developed by ISRA, Senegal (Annual report of Cisse, Sene and Sall 2001). ISRA-819 has large, smooth, brown seed, a very short cycle from sowing to maturity, and resistance to cowpea aphid, and the seed-borne diseases bacterial blight and cowpea aphid-borne mosaic virus. ISRA-819 was selected from a cross between Melakh and the local land race Ndiaga Aw. Multi-location tests were conducted during the rainy season of 2000 in which ISRA-819 was compared with parents Ndiaga Aw and Melakh, and Mouride in six villages in the Peanut Basin of Senegal. Four experiments were conducted in each village that were managed by four farmers. Experiments had individual plots of10 rows, 5 m long with 50 cm between rows and 25 cm between seeds that were replicated three times. Experiments in two villages in the Louga Region were destroyed by hairy caterpillars. In the four other villages, pesticides were not applied and useful yields of grain were obtained averaging 679 kg/ha (Table 1).

Table 1. Grain Yields in Multi-location Trials in Villages in Senegal in 2000.

	Villages				
Varieties	Golobé	Ndande	Ndoucoumane	Mérina	Mean Yield
	----------kg/ ha ----------				
Melakh	942	771	723	726	790
Mouride	912	694	657	726	747
ISRA-819	853	646	678	741	730
Ndiaga Aw	584	467	287	459	449
CV%	20	20	24	14	679
LSD .05	216	186	175	190	

ISRA-819 had similar grain yields as the two new varieties, Melakh and Mouride, that were significantly greater than the grain yields of the land race, Ndiaga Aw, in all of the four villages. Farmers reported that they liked the taste of ISRA-819.

A similar experiment was conducted on the CNRA research station at Bambey. Sowing was done on July 23, 2000, and 640 mm of rainfall occurred that was distributed well throughout the growing season (This was a relatively wet year at Bambey but further north in the Peanut Basin at Thilmakha the rainfall was only 392 mm). A pre-sowing application of fertilizer was made which applied 9, 30 and 15 kg/ha of NPK, respectively. Two sprays of decis were provided at early flowering to control flower thrips.

Table 2. Varietal Performances in a Trial at CNRA, Bambey, Senegal in 2000.

Varieties	Grain Yield	Grain Size	Cycle Length
	kg/ha	mg/seed	days
Melakh	2433	219	62
Mouride	1986	178	75
ISRA-819	1840	245	62
Ndiaga Aw	1662	181	77

It is clear that ISRA-819 has a very large grain (Table 2), which is a trait appreciated by farmers and consumers. Also, the short cycle of both Melakh and ISRA-819 is appreciated because it shortens the period of hunger that often occurs in September. The yield potential, as indicated by the performance of ISRA-819 at Bambey (Table 2) appears reasonable. The only potential flaw in ISRA-819, detected to date, is that it may be very sensitive to flower thrips. A market is present in Senegal for the large brown grain of ISRA-819. The potential for export of ISRA-819-type grain is not known. In the summer of 2001, 60 on-farm tests were conducted in 12 villages to further evaluate ISRA-819. Also, an NGO, Promono, has begun to evaluate ISRA-819. Reports on these tests will be available in 2002.

Tests were conducted in the summer of 2000 at CNRA, Bambey with 23 advanced lines selected from a cross between Melakh and Mouride using a randomized block design with four replicate blocks. Average grain yields over 1999 and 2000 indicated that seven of the lines may have greater yield potential than Melakh and Mouride (Cisse, Sene and Sall 2001). These advanced lines also have grain that has a similar large size as that of Melakh. Another set of 23 advanced lines which came from other crosses were evaluated at CNRA, Bambey in the summer of 2000. Four lines were identified with potential grain yields equivalent to or larger than Mouride and Melakh but with much larger grain (233 to 274 mg/seed compared with 216 and 186 for Melakh and Mouride) which may be particularly desirable to consumers. These lines came from the cross Melakh x ISRA-283(Diongama). A preliminary yield test with three randomized blocks was conducted at CNRA, Bambey during the summer of 2000 to evaluate 21 lines selected from a cross between Baye Ngagne and ISRA-514. The objective was to obtain a variety with the grey speckled seed type of the traditional variety, Mougne. Several lines were selected for advanced trials in 2001. During the dry season of 2000/2001, various breeding populations were advanced in a field at CNRA, Bambey using irrigation. During the summer of 2001, 94 new breeding lines were evaluated in preliminary and advanced yield trials at Bambey and Thilmakha. Early generation breeding populations were advanced and single-plant selections were made in them, and more crosses were made.

Varieties and breeding lines were screened for resistance to the parasitic weed *Striga gesnerioides* during the summer of 2000 (Wade and Dièye 2001). Mouride and 23 breeding lines were compared with the striga susceptible variety Mougne in pots at CNRA, Bambey. Mouride and lines 907, 867 and 880 showed complete resistance to striga. The same materials were evaluated in a striga infested field at Ngalbane and only lines 867, 880 and 907 showed some resistance to striga. A set of 19 breeding lines from IITA, Kano were compared with Mougne in both a pot study at CNRA, Bambey and in the naturally infested field at Ngalbane. Seventeen of the IITA lines showed complete resistance to striga in both experiments. As was observed in earlier years, Mouride only has partial resistance to the striga biotypes present in Senegal and the IITA lines from Kano should be used as parents in breeding because they appear to have complete resistance to the striga biotypes present in Senegal.

A study was conducted at Nioro in the summer of 2000 with lines having delayed leaf senescence that were bred by a UCR/ISRA shuttle breeding program (Ndiaye 2001). The study demonstrated that these lines exhibit two flushes of flowering under these conditions. The first flush began 35 days from sowing and ended 61 days from sowing. The second flush began 66 days from sowing and ended 87 days from sowing.

UCR, California Trials: Blackeye-type cowpea breeding lines were evaluated in replicated experiments at the Kearney and Shafter, Research and Extension Centers of the University of California in the summer of 2000. The lines had been bred for combinations of traits including: large grain size, resistances to races 3 and 4 of Fusarium wilt, broad-based resistance to root knot nematodes, heat tolerance at flowering, and chilling tolerance at emergence. Thirty-two lines were tested in two preliminary trials at each center with 16 entries being compared with the current cultivars CB46 and CB27. The experimental design consisted of three replications arranged in randomized blocks and individual plots being 4 rows, 6 m long with 76 cm between rows and approximately10 cm between plants. Trials were sown on May 25th and 26th and cut on September 19th and 15th at Kearney and Shafter, respectively. The line with the highest grain yields (UCR 00-541) (Table 3) produced 6130 kg/ha at Kearney and 4931 kg/ha at Shafter compared with yields of CB46 of 4572 kg/ha and

4236 kg/ha at these locations (Ehlers, Hall, Roberts, Matthews and Sanden 2000). The breeding program appears to be effective in enhancing yield potential. Several lines had greater yields than either CB46 or CB27, and UCR 00-524 and UCR 00-516 also had large high quality grain (Table 3). These 32 lines were also evaluated for resistance to gene *Rk*-virulent *M. incognita* root-knot nematodes in growth pouches during the spring of 2000, for resistance to *M. javanica* root-knot nematodes in a special infested field site at the Kearney Research and Extension Center, for resistance to Fusarium wilt using a seedling root-clip-dip pot test in the greenhouse during the spring of 2000 and for heat tolerance using a summer planting at the Coachella Valley Agricultural Research Station in 2000 (Table 3). Line UCR CT 15 is the first cowpea breeding line with chilling tolerance at emergence to be tested in replicated grain yield trials (Table 3).

Table 3. Resistance and tolerance features, grain yield and individual seed weight determined in 2000 for CB27, CB46 and ten selected breeding lines developed at UCR. Resistance and tolerance features of CB5 also included, but it was not in the current yield trials.

	Fusarium wilt		Root-knot nematodes					
			M. incognita		*M. javanica*	Heat	Grain	Seed
Entry	Race 3	Race 4	avirul.	virulent		Tolerant	Yield	Weight
							-t/ha	mg/seed
CB5	No	No	Yes	No	No	No	-------	- ----
CB46	Yes	No	Yes	No	No	No	4.51	207
CB27	Yes	Yes	Yes	Yes	Yes	Yes	4.20	224
UCR 00-541	Yes	Yes	Yes	Yes	Yes+	Yes	5.53	207
UCR 00-524	Yes	Part.	Yes	No	No	Yes	5.01	259
UCR 00-516	Yes	Yes	Yes	Yes	Yes	Yes	4.91	243
UCR 00-539	Yes	No	Yes	Yes	Yes	Yes	4.86	222
UCR 00-517	Yes	Yes	Yes	Yes	Yes+	Yes	4.69	244
UCR 00-515	Yes	Yes	Yes	Yes	Yes	Yes	4.60	241
UCR 00-521	Yes	Part.	Yes	No	Less gall	No	4.58	221
UCR 00-509	Yes	Yes	Yes	Yes	Yes	Yes	4.54	225
UCR 00-540	Yes	No	Yes	No	No	Yes	4.47	229
UCR CT 15	Yes	No	Yes	No	No	Yes	4.38	258

avirul. = avirulent, effectively controlled by gene *Rk*; virulent = not effectively controlled by gene *Rk* alone; Yes+ =less root galling than CB27; Less gall=less galling than CB46, similar in galling to CB27 at Kearney *M. javanica* site in 2000.

Nine of the ten highest yielding lines were selected and tested in advanced trials conducted at four locations in California in 2001. One hundred and thirty-three new crosses were made at UCR in 2000-2001. Of these, eight crosses were made between large white breeding lines developed from the Brazilian line Montiero and CB27 or CB46, forty-six crosses were made between lygus resistant breeding lines and CB27 or CB46, forty-two crosses were made to incorporate the sweet trait into an adapted genetic background and combine it with the green trait. Eleven crosses were made between green seeded breeding lines and CB27 and CB46 to continue development of persistent green versions of these high yielding varieties. Twenty-six crosses were between elite blackeye breeding lines and varieties listed in Table 3. The 26 crosses were made to combine large seed size (e.g. from UCR 00-524) and broad-based nematode and Fusarium wilt resistance (e.g. from UCR 00-517), yield potential (e.g. from UCR 00-541) and chilling tolerance at emergence (e.g. from UCR CT 15). All of the F_1's were grown out in a greenhouse during the spring of 2001 and large F_2 populations were planted at Riverside in the summer of 2001 from which many selections were made.

Breeding nurseries with early and late generation materials were grown at Riverside, Kearney and Shafter in the summer of 2000 and single plant selections were made. Two advanced lines that appeared especially good were bulk harvested from the nursery at Kearney to obtain sufficient seed for yield testing in the summer of 2002.

Breeding lines were advanced and seed was multiplied during the spring, fall and winter in greenhouses and in off-season nurseries in the spring and fall in Coachella Valley, California with the spring planting being in early March and the fall planting in mid-August with harvesting in early June and December, respectively. The fall off-season nursery is particularly useful because it has hot to warm short days and any type of cowpea, including ones from Africa with strong sensitivity to photoperiod for flower initiation, will produce substantial grain in this environment.

IRAD/Cameroon: Germplasm development at IRAD involves (1) the introduction and testing of materials from other CRSP projects (Senegal, Ghana and UC Riverside) and from IITA, and (2) collection and screening of local materials obtained over the last several years thanks to the price and quality study conducted by IRAD in collaboration with Jess Lowenberg-DeBoer. From IITA, several cowpea international trials with 20 entries each were established: Extra-early maturity, Medium savannah, Striga resistance, Virus resistance, and Insect resistance (no spray). Materials of CRSP origin evaluated included forty lines from Cameroon, UCR, Ghana and Senegal. Lines with promising virus, disease, insect or Striga resistance and with grain yield of 2000 kg/ha and above were recorded, and these will be further evaluated in a regional trial to test for adaptation and/or for potential use as parents in the crossing program.

SARI/Ghana: Breeding for appropriate maturity period (extra-early, early and medium/late): The development of improved cowpea varieties of varied maturity for the various ecological zones of northern Ghana was vigorously pursued this year by including one more testing site at Yendi.

In the extra-early division, twenty lines were tested in a total of four sites (Nyankpala, Damongo, Manga and Yendi). Grain yield averaged about 900kg/ha but no variety matured in less than 60 days. The earliest was (IT98K-463-6) 63 days. If meaningful advances from other institutions as well as intensify local collection to augment the existing gene pool.

The maturity period in the early category ranged between 63 and 70 days. Even though Bengpla remains the earliest, varieties with almost one and a half times its yield potential but which mature in about 70 days have been identified. The difference of one week may be significant statistically but the higher yield of the later maturing varieties more than offsets this apparent disadvantage. Farmers would be more willing for this trade-off.

Due to problems of excess moisture soon after planting and bird damage at emergence, which jointly resulted in a lower plant stand for some plots, grain yield was lower in the medium/late materials than expected. However, yields of up to 1600kg/ha have been recorded for a good number of entries.

Screening for resistance to Striga gesnerioides: The screening for resistance against Striga is done at Manga where a Striga-sick plot has been established. Field observations indicate that many lines appear tolerant, as plant growth was good despite the emergence of Striga close to them. Clearly, the check variety (Bengpla) manifested signs of stunted growth and pre-mature yellowing of leaves. As Manga is far away from the Nyankpala campus close observation and monitoring, as should be the case, cannot be done. It is suggested to establish another sick-plot at Nyankpala to facilitate the screening process in the coming years.

Development of dual-purpose cowpea: Attempts are also being made to develop dual-purpose cowpea to satisfy the growing demand for livestock feed. Some varieties have been observed to possess quite a good combination of grain and fodder and these would be advanced to a full trial to determine their suitability.
1.A.1.b.(3)(j) Current status of research: For a breeding program to be effective, all steps must be conducted every year to generate a continuous flow of new varieties. These steps include making new crosses, advancing generations, making selections, bulking seed and conducting various performance trials. ISRA, Sénégal and UCR have mature breeding programs that are proceeding efficiently and effectively. The SARI, Ghana and IRAD, Cameroon cowpea breeding programs are being developed at this time.
1.A.1.b.(3)(k) Documented impact: This type of research has beneficially impacted farmers and consumers through the release of new cowpea varieties in Senegal, Cameroon, Ghana and Sudan, and an InterCRSP project managed by World Vision International has been extending these cowpea varieties to other African countries.

I.A.1.b.(4) Activity #4: Develop and test ideotypes for intercropping with maize and sorghum.
I.A.1.b.(4)(a) Priority: (2) High priority
I.A.1.b.(4)(b) U.S. researchers: None
I.A.1.b.(4)(c) HC researchers: Marfo
I.A.1.b.(4)(d) Methodology: Three years fo investigations in northern Ghana indicate that specific cowpea traits are needed for optimal performance under cowpea-maize-sorghum intercropping. Varieties having potential “intercropping” traits would be field tested under maize-cowpea intercropping in the dry and wet savannas of Ghana with economic analyses of the results. Different proportions of maize to cowpea are being evaluated at the two sites.
I.A.1.b.(4)(e) Anticipated (1 year) results of activity: Specific traits identified for intercropping systems.
I.A.1.b.(4)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Efficiency of cowpea breeding for intercropping enhanced	The project will end this year	

I.A.1.b.(4)(g) Budget:

SARI	$2,800
Total (Direct costs only)	$2,800

I.A.1.b.(4)(h) Major changes:

I.A.1.b.(4)(i) Progress during past year: After years of testing some lines for their suitability as intercrop partners to sorghum and maize, it was concluded that an intercrop combination of one row of cowpea to one row of maize was most ideal for both partners. Also Sul 518-2 emerged the best of the three varieties tested: Sul 518-2, *Bengpla* and *Sumbrisogla*. However, the evaluation using sorghum was not concluded and would have to continue.

I.A.1.b.(5) Activity #5: Test potential new screening methods for lygus bug, flower thrip and pod sucking bug resistance.
I.A.1.b.(5)(a) Priority: (1) Essential
I.A.1.b.(5)(b) U.S. researchers: Hall, Ehlers
I.A.1.b.(5)(c) HC researchers: Salifu
I.A.1.b.(5)(d) Methodology: 1) UCR has discovered cowpea lines for which emasculated, unpollinated flowers do not abscise and form pods (they are parthenocarpic). This trait may confer resistance to insects that cause floral bud abscission, such as lygus or thrips and is much easier to screen for than is resistance to these insect pests. We will evaluate a set of randomly derived lines with and without parthenocarpy for resistance to lygus bug and flower thrips in the field and determine if there is an association of resistance with the parthenocarpic trait. 2) UCR has discovered that lygus bugs will feed on imbibed cowpea seed and that the damage done to the seed is similar to that occurring in the field and can be visually evaluated. UCR will attempt to develop a preference type laboratory screening method based on this observation and screen many cowpea accessions. A successful screening technique of this type also could be effective with other piercing and sucking insects such as pod bugs and the southern stink bug.

Ghana: Twenty-six lines including a resistant (TVx3236) and susceptible (*Bengpla*) checks were planted in randomized complete blocks replicated four times to evaluate them for resistance to flower thrips. Plot size consisted of two rows 5m long; distance between rows 0.75m. One set of the experimental layout was protected with insecticide at pre-flower and flowering to control thrips damage while the second set was not protected. This was an attempt to assign levels of yield loss due to thrips on each of the test lines. Additional data included visual rating (on a 1-5 scale) of five consecutive plants within the row for thrips damage at ca. 35-40 days after planting (DAP).
I.A.1.b.(5)(e) Anticipated (1 year) results of activity: These experiments will determine 1) whether parthenocarpy is an important new insect resistance mechanism and 2) whether a screening method based on imbibed seed is effective in detecting genetic differences in cowpea.
I.A.1.b.(5)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Faster progress in developing insect resistant cowpeas and ultimately varieties with a reduced need for insecticides to get high yields	Three years	Use of parthenocarpic trait or imbibed seed screening procedure by cowpea breeding programs

I.A.1.b.(5)(g) Budget:

SARI	$ 3,000
UCR	10,000
Total (Direct costs only)	$13,000

1.A.1.b.(5)(h) Major changes: The commercial company UCR had used to obtain large numbers of lygus stopped providing these insects and UCR could not test the seed screening method this year. Research by UCR at the Kearney Research and Extension Center in the summer of 2000 indicated that the parthenocarpic trait may not be effective in controlling lygus and the level of flower thrip resistance also was not high in the parthenocarpic lines in Ghana (refer to the previous annual report). Consequently, UCR increased efforts on using conventional non-sprayed plots versus sprayed plots approach to screening for lygus resistance and this work is reported in section 1.A.2.b.(1) and also increased efforts in breeding new grain types as reported in section 1.A.4.b.(1).
1.A.1.b.(5)(i) Progress during year UCR, California**:** Reported in section 1.A.2.b.(1).

Ghana: Of four parthenocarpic lines evaluated, 547-10 (parthenocarpic, hairy) scored a mean thrips damage rating of 1.5 and 30.1% yield loss due to thrips. This is consistent with its performance in 2000. The resistant check TVx3236 scored a mean thrips damage rating of 1.2 and 8.5% for thrips damage and yield loss due to thrips respectively. The other parthenocarpic lines 941-20, 941-11, 548-5 were rated 2.0, 2.7, 3.0 respectively for thrips damage and suffered yield losses due to thrips of 40.2, 49.5 and 67.8% It appears that parthenocarpy has a role to play in thrips and to some extent pod sucking bug resistance. The data gathered from the field in which natural infestations are relied upon need to be augmented by close-up detailed screenhouse related studies. The effectiveness of the insect resistance studies at SARI have generally been hindered by the lack of screenhouse facilities for such followup studies. Hopefully this constraint may be resolved during the following years. The results of the study shows promise as an insight to assist breeders in understanding the role parthenocarpy plays in conferring resistance.
1.A.1.b.(5)(j) Current status of research: Conventional approaches should be used to screen plants for resistance to lygus, flower thrips and pod bugs until more effective new methods are developed (refer to section 1.A.2.b.(1)).
1.A.1.b.(5)(k) Documented impact: Varietal resistance to insect pests has tremendous potential for enhancing the yield and environmental safety of cowpea production systems in Africa and elsewhere.

I.A.1.b.(6) Activity #6: Effective heat tolerance for tropical Africa
I.A.1.b.(6)(a) Priority: (1) Essential
I.A.1.b.(6)(b) U.S. researchers: Hall
I.A.1.b.(6)(c) HC researchers: Cisse, Thiaw
I.A.1.b.(6)(d) Methodology: Heat tolerance in subtropical germplasm has been associated with slow electrolyte leakage from heated leaf discs in research at UCR. Electrolyte leakage is a potentially more efficient screening method than field based methods, especially in Africa where insect damage occurs that mimics heat damage to reproductive structures. Research would be conducted at UCR to determine whether there is an association between heat tolerance and slow electrolyte leakage from leaves using a genetic selection approach that also would develop cowpea lines with reproductive stage heat tolerance. Heat-tolerant lines that are developed will be evaluated in subtropical California conditions and tropical Senegal conditions by ISRA. In Senegal, six pairs of lines with and without heat tolerance will be evaluated with early June sowing to evaluate the combined effects of heat and long days. Earlier studies in Africa with these lines showed no differences between the lines but they were conducted with late sowing and under hot but short days.
I.A.1.b.(6)(e) Anticipated (1 year) results of activity: Determine the comparative usefulness of leaf electrolyte leakage screening and field screening for flowering and pod set in a very hot

subtropical environment in breeding for heat tolerance.

I.A.1.b.(6)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Improved heat-tolerant germplasm and heat tolerance screening methods that are effective in Africa	Three years	Use of electrolyte leakage screening method by cowpea breeders in Africa

I.A.1.b.(6)(g) Budget:

ISRA	$ 3,000
UCR	4,000
Total (Direct costs only)	$ 7,000

1.A.1.b.(6)(h) Major changes: No changes

1.A.1.b.(6)(i) Progress during past year ISRA, Senegal Trials: Six pairs of lines that either have or do not have heat tolerance under California conditions were compared together with Melakh and Mouride at CNRA, Bambey, Senegal with sowing on June 22, 2000, to achieve hot long day conditions during the vegetative stage (Cisse, Sene and Sall 2001). The California lines flowered earlier (34 to 36 days from sowing) than either Melakh (39 days) or Mouride (44 days). The California lines also had a shorter cycle length from sowing to maturity (56 to 61 days) compared with Melakh (63 days) and Mouride (67 days). The heat-tolerant lines, however, had similar low grain yields (1004 kg/ha) as the heat-sensitive lines (1008 kg/ha) and they were much less than those of Melakh (1560 kg/ha) and Mouride (2121 kg/ha). Also, the heat-tolerant and heat-sensitive lines did not differ in either pod set or harvest index in contrast with the large differences that have been observed in hot long-day conditions in California. Another study was conducted at CNRA, Bambey in 2000, with four of the six pairs of lines using Mouride and landrace 58-57 as controls (Ndiaye 2001). The trial was sown on July 23, 2000. No differences were observed in any traits between the heat-tolerant and heat-sensitive lines. Yield levels were extremely low, however, with the landrace giving only 113 kg/ha, Mouride only 838 kg/ha and the California lines averaging 671 kg/ha. No explanation was given for the very low yields. Mouride typically has produced grain yields of 2000 to 2500 kg/ha at CNRA, Bambey. Six trials with the same lines in earlier years in Senegal and northern Ghana gave similar results: no differences between heat-tolerant and heat-sensitive lines and overall low yields (Hall, Ismail, Ehlers, Marfo, Cisse, Thiaw and Close 2002). The reproductive-stage heat-tolerance genes discovered by A. E. Hall and associates have been effective in hot subtropical conditions in California (Hall et al. 2002) but for tropical conditions there are two possibilities: either 1) these genes are not effective in the tropics under either hot long-day or hot short-day conditions or 2) these genes may be effective in tropical conditions providing other stresses do not damage plant growth and development. Consequently, either these heat-tolerance genes are not useful in tropical zones in Africa or they may be effective in Africa providing they are combined with other genes conferring adaptation to specific target production environments and this approach was used by Dr. K. O. Marfo in developing the variety Sul 518-2 for northern Ghana. The heat tolerance of Sul 518-2 came from accession TVu 4552 and was incorporated in California using the methods developed by the CRSP project at UCR. Studies by B. B. Singh indicate that reproductive development of many cowpea accessions is damaged by hot long day conditions in northern Nigeria and a parent used by UCR in breeding, TVu 4552, was heat tolerant under these conditions. This evidence supports the argument that the heat-tolerance genes in TVu 4552 may be effective in tropical Africa providing they are combined with some other genes needed for adaptation to these environments.

UCR, California Experiments: A genetic selection experiment is being conducted in California to test whether heat tolerance can be enhanced by selecting for low electrolyte leakage from leaf disks incubated in water under aerated conditions for six hours at 46° C. Reciprocal crosses were made between a heat-sensitive cultivar with high electrolyte leakage (CB5) and a heat-tolerant line, H36, which has less electrolyte leakage than CB5. H 36 has heat-tolerance genes from TVu 4552 but similar genetic background as CB5 in that it was bred using two cycles of backcrossing with CB5. The F_1 plants had been selfed to produce F_2 seed. One hundred and twenty F_2 plants were screened and used to develop thirty-two lines by selecting for low (16 lines) and high (16 lines) electrolyte leakage in the F_2 and F_3 generations. These lines were advanced to the F_5 generation in greenhouses. During the summer of 2001, three sets of these 32 F_6 lines were evaluated for heat-tolerance, electrolyte leakage and agronomic traits in very hot field and greenhouse conditions, and in a field environment with more optimal temperatures. Another set of 300 F_2 plants from CB5 x H36 were grown in a very hot field environment during the summer of 2000. Forty plants were selected as being heat-sensitive in that they exhibited floral bud suppression and produced few flowers and 66 plants were selected as being heat-tolerant in that they produced abundant flowers and pods. Selected plants were advanced three generations in a glasshouse. During the summer of 2001, these 106 F_6 lines were evaluated for heat-tolerance, electrolyte leakage and agronomic traits in very hot field and greenhouse conditions and in a field environment with more optimal temperatures. During the fall of 2001, all of the F_6 lines (32 + 106) also are being evaluated in hot short-day conditions in a glasshouse at UCR. The heat tolerance, electrolyte leakage and agronomic traits of these lines are being determined in this study.
1.A.1.b.(6)(j) Current status of research: Analysis of the data obtained during the summer and fall of 2001 may indicate whether selecting for electrolyte leakage from leaf disks can be used by plant breeders to enhance heat tolerance in cowpea.
1.A.1.b.(6)(k) Documented impact: This research will contribute to impact if it results in a more efficient method for plant breeders in the tropics to select for heat tolerance and thereby enhance grain yields.

I.A.2. Research area: Discover and utilize pest resistance traits in cultivated and wild x cultivated cowpea germplasm and land races.

I.A.2.a. Background: Insect pests are a major constraint to cowpea production in Africa and other parts of the world. Insect pest resistant cowpeas would generate a “green revolution” for this crop with widespread economic and health benefits to farmers and consumers. Moderate levels of insect resistance have been identified to some important pests such as cowpea aphid, bruchids, flower thrips and lygus bug, but stronger resistance is needed to dramatically increase production when insecticides are not used and to reduce insecticide usage. There are no candidate trans-genes for resistance to lygus or flower thrips so resistance must be sought in cultivated cowpea or progenies developed from wild cowpea x cultivated cowpea crosses. Screening of cultivated cowpea for resistance to lygus should continue as only a small fraction of the world’s available accessions of cultivated cowpea have been evaluated. Also, there is a need to assess wild cowpea germplasm as sources of genes for resistance to flower thrips, pod sucking bugs and lygus. This is best accomplished by screening germplasm developed from wide crosses between wild and cultivated cowpeas and not by screening wild cowpeas because some wild traits conferring resistance (i.e very tough seed coats) are not acceptable to consumers. Sustainability of cropping systems can be enhanced by developing cowpea varieties that are resistant to nematode pests. Use of these varieties would reduce yield losses to cowpeas from these pests and also decrease the populations of the nematodes in the soil which can benefit subsequent crops that are susceptible to the nematodes.

I.A.2.b. Proposed research area workplan and subsequent annual progress report

I.A.2.b.(1) Activity #1: Breed wild x cultivated and cultivated cowpea germplasm and screen it for pest resistance.
I.A.2.b.(1)(a) Priority: (1) Essential
I.A.2.b.(1)(b) U.S. researchers: Hall, Ehlers, Shade
I.A.2.b.(1)(c) HC researchers: Cisse, Balde, Salifu
I.A.2.b.(1)(d) Methodology: Lines will be selected from segregating populations originating from crosses between *Vigna rhomboidea* and cultivated cowpea developed at IITA, and from crosses between *Vigna unguiculata* subspecies *mensensis,* subspecies *dekindtiana* and subspecies *pubescens* and cultivated cowpea developed at UCR. In addition, a large array of cultivated cowpea lines from IITA will also be evaluated, including lines developed by C.A. Fatokun from crosses between two unique sources of flower thrips resistance that have shown transgressive segregation for resistance to this pest. Specialized, unprotected field screening nurseries located in insect pest 'hot-spots' will be used to evaluate diverse arrays of cultivated and wild x cultivated germplasm. Similar nurseries will be used to screen breeding populations to incorporate existing resistance into adapted genetic backgrounds. Frequent placement of check cultivars, use of susceptible cowpea in earlier planted 'spreader rows and selective spraying of non-target pests may be used as appropriate. Visual evaluation of flowering and podset, and measures of seed damage will be used in preliminary assessments of resistance. Replicated trials with protected and unprotected trials will be used to confirm and quantify levels of resistance of very promising lines. SARI will screen for resistance to flower thrips and pod sucking bugs. ISRA will screen for resistance to flower thrips. UCR will screen for resistance to lygus bugs.
I.A.2.b.(1)(e) Anticipated (1 year) results of activity: Identification and incorporation of new sources of resistance to lygus bug, flower thrips, and pod sucking bugs.
I.A.2.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
New and stronger sources of insect pest resistance will allow the development of cowpea varieties with stronger insect pest resistance and reduced need for insecticides		Discovery of lines with strong resistance to specific insect pests

I.A.2.b.(1)(g) Budget:

SARI	$ 4,000
ISRA	3,000
UCR	10,750
Total (Direct costs only)	$17,750

1.A.2.b.(1)(h) Major changes: More work was done by UCR on this activity due to less effort being spent on the activity described in section 1.A.1.b.(5).
1.A.2.b.(1)(i) Progress during past year UCR, California Studies: Lygus is the major insect pest of cowpea grown in California, damaging floral buds, flowers and grain. Wild cowpea are a potential source of insect resistance genes, but are themselves difficult to evaluate for

resistance to lygus because of their photoperiod sensitivity, which may cause them not to flower in California in the summer, and the presence of morphological characteristics, such as tough seed coats, which may confer some resistance to lygus but be of no use in cultivars. A similar problem can occur when using wild germplasm as a source of flower thrip resistance. Lygus and flower thrip resistance traits are needed that can be used in cultivars. The approach used at UCR is to do some pre-breeding using a single backcross ((wild cowpea x cultivar) x cultivar) to produce lines that have similar phenological and seed traits as cultivars but still contain many genes from the wild parent. These lines are then screened for lygus resistance after which resistant lines are crossed to the cultivar and segregating progeny are produced that are screened again for lygus resistance. In this way, lines are produced that have both resistance to lygus and the other necessary agronomic traits.

UCR continually imports insect resistant wild x cultivated lines and breeding lines developed by IITA. In 2000, UCR screened 113 cowpea breeding lines for resistance to lygus bug that UCR had received from IITA and multiplied in the greenhouse the previous fall. Also in 2000, UCR imported additional materials from IITA, including 6 wild x cultivated lines showing insect resistance at IITA, and 66 other breeding lines (including 20 lines from IITA's 'no-spray' Cowpea International Trial). To avoid introduction of viruses, these lines were grown out in the greenhouse during the fall of 2000. In addition, these 72 lines were planted in an unprotected trial with 2 replications (2 row plots) at Kearney in 2001 and evaluated for resistance to lygus bug.

During the spring of 2000, 17 F2 populations developed from crosses between wild x cultivated cowpea breeding lines and cowpea breeding lines were grown at the Coachella Valley Agricultural Research Station. Eight of the crosses involved insect resistant lines developed at IITA from crosses between *Vigna unguiculata* ssp *dekintiana* var *rhomboidiae* wild cowpeas and IITA cowpea breeding lines, while the remaining crosses used wild x cultivated parents developed at UCR from crosses between wild cowpea *Vigna unguiculata* ssp *pubescens* and cowpea varieties CB46, CB27 and CB3. Ninety selections were made that were planted as F3 families at Riverside under unprotected conditions in the summer of 2000 and 30 were selected that exhibited little damage from lygus. In addition, 32 and 10 more advanced lines were screened for lygus resistance at Riverside and Kearney, California, respectively. Included in these trials were the parental wild x cultivated lines used in the 17 crosses noted above. Lygus-resistant lines selected during the summer of 2000 were re-screened in California during the summer of 2001.

The strategy UCR uses for screening for lygus resistance begins with growing either single-row plots or two-row plots of new accessions and breeding lines in unprotected nurseries in locations, i.e Kearney, CA, where strong attacks from lygus often occur. Selections are made which are then tested in unprotected larger, replicated plots. Further selections are made after which smaller numbers of lines are evaluated in large unprotected and protected plots with more replications. In the summer of 2000, 7 advanced lygus-resistant lines were compared with CB46 in unprotected and protected plots replicated four times at Kearney (Ehlers, Hall, Roberts, Matthews and Sanden 2000). A wild x cultivated line bred by UCR (96-11-27)had less loss in grain yield due to lygus (13%) than CB46 (29%). This line also had fewer seed damaged by lygus (12%) than CB46 (22%) and a wild x cultivated line developed by IITA (IT95M-43) had the fewest damaged seed in this year (7%). An additional 92 breeding lines were evaluated in three unprotected trials with replicated 2-row plots at Kearney in 2000. These lines were scored by J. Ehlers of UCR and R. Shade of Purdue and 10 lines exhibited less lygus damage to pod set or grain than CB46 and CB27. These lines were included in protected/unprotected trials conducted at Kearney during the Summer of 2001. During the Fall of 2000, these lines were multiplied in the greenhouse to obtain sufficient seed for replicated trials conduct in 2001. Crosses were also made in the greenhouse between these ten resistant lines and CB46 and CB27. The F1's were grown in the greenhouse to produce F2 seed during the Spring of 2001. Large F2 populations from these crosses were planted under unprotected conditions at Kearney in the summer of 2001 and single-plant selections made for pod set and low seed damage. Progress is being made in incorporating lygus resistance into cultivars adapted to California but the work is difficult and progress is slow.

Cowpea aphid is the second most damaging insect pest of cowpea in California. Cowpea lines that resist cowpea aphid in Africa are not effective in California because California has a different biotype of cowpea aphid. UCR discovered that UCR 5038 has resistance to the California biotype. Unfortunately, UCR 5038 has many undesirable traits. Since 1996, UCR has been breeding to incorporate this resistance into a desirable genetic background. In the summer of 2000, 28 cowpea lines were evaluated in a screening nursery at Kearney which had a strong natural infestation of cowpea aphid. All of the lines were damaged by the aphid attack but lines differed in the extent of recovery ranging from complete recovery to no recovery. Lines with strong recovery from the attack by cowpea aphid included: UCR 5038, two of ten lines bred to incorporate the resistance from UCR 5038, two accessions from IITA (IT93K-2046 and IT93K-503-1), two lines bred to incorporate lygus resistance using IT93K-2046 as a parent, and accessions from Botswana (UCR 779) and India (UCR 1340). Lines showing recovery resistance to cowpea aphid were screened again in a nursery at Kearney in the summer of 2001 and exhibited similar levels of recovery resistance to cowpea aphid. These results appear very reliable in that IT93K-503-1, IT93K-2046 and UCR 779 have shown strong recovery resistance to cowpea aphid in trials in two years. These results are very important because this is the first case of an induced type of resistance to cowpea aphid that has been reported for cowpea and the resistance is strong enough in California to be of considerable agronomic value. UCR has crossed IT93K-503-1 with CB46, which has a moderate level of recovery resistance, to amplify the program on breeding for cowpea aphid resistance for California. The utility of this resistance for Africa is not known but the breeder in Burkina Faso said that they have encountered a biotype of cowpea aphid that is overcoming the conventional sources of resistance used by African breeders. UCR will send him seed of the lines that showed resistance to cowpea aphid in California so that he can test them in Africa.

ISRA, Sénégal studies: In the summer of 2000, the flower thrip resistance of 20 lines was evaluated at Bambey, Senegal in sprayed and unsprayed plots with three replications (Cisse, Sene and Sall 2001). For the unsprayed plots, Bun 22 from Ghana had the smallest population of thrips, the least damage to floral buds but only a moderate grain yield (616 kg/ha) presumably due to its low yield potential (779 kg/ha in sprayed plots). These results illustrate the value of the CRSP promoting the exchange of germplasm among breeding programs in Africa. Daipel and Sansi from Ghana also had small populations of thrips, slight damage to floral buds but only moderate to small grain yields (763 and 467 kg/ha) and moderate yield potential (914 and 879 kg/ha in sprayed plots). Two flower thrip resistant controls from IITA, TVx 3236 and TVu 1509, had moderate populations of thrips, slight damage to floral buds and moderate to low grain yields (675 and 488 kg/ha) and high to low yield potential (1415 and 595 kg/ha in sprayed plots). ISRA-2065 had moderate levels of thrips, slight damage to floral buds and fairly high grain yields (829 kg/ha) and high yield potential (1554 kg/ha in sprayed plots). KVx404-22-2 had moderate levels of thrips, moderate damage to floral buds and high grain yields (1032 kg/ha) and high yield potential (1599 kg/ha in sprayed plots). Of particular importance, Melakh had high levels of thrips but only slight damage to floral buds, the highest grain yield (1169 kg/ha) and only moderate yield potential in this trial (1223 kg/ha in unsprayed plots). This meant that grain yield of Melakh was not significantly affected by flower thrips. Non-sprayed trials in earlier years have suggested that Melakh has useful tolerance to flower thrips. In the summer of 2000, it was observed that a selection made from land race Ndiaga Aw may have some resistance to hairy caterpillar and similar results were obtained in 2001. This result may be important because hairy caterpillar can devastate cowpea in the Sahelian zone of Sénégal and varietal resistance may offer the only solution to this problem.

Twenty-eight cowpea varieties and breeding lines were screened for resistance to flower thrips at Nioro in the summer of 2000 (Balde, Diop and Thiam 2001). Sprayed and unsprayed blocks were used. Several lines had fewer thrips and less reduction in pod production than the control TVx 3236.

Ghana: The 2001 trial on insect resistance was designed as a holistic activity using participatory varietal selection procedures and conducted at Yendi. Participants of the Training of Trainers and Farmer Field Schools run to test pilot IPM technologies that were involved in the activity. Fifteen cowpea lines originating from UCR and Clemson were evaluated. The 21 trainee extension workers were asked to make a walk through the array of varieties and later score each of them for traits they considered most important for a cowpea crop. This exercise was conducted at the farmer field schools later by these trainers at their respective locations.

For purposes of clarity their descriptions were grouped under 10 traits, namely: maturity period, yield potential, haulm, seed/pod size, resistance to pests, emphasizing thrips and pod sucking bugs, resistance to drought, crop uniformity on the field, plant height at maturity, color of pod and growth habit (erect, prostrate, semi-erect, etc.).

The results indicated that yield potential was the most important trait, followed by maturity period, plant height and resistance to pests and diseases, respectively, as presented in Table 1. In terms of preference based on the expression of these traits in the various varieties, Asontem and Clemson 15 were jointly rated at the top with a score of 21 while Bengpla, Clemson 16 and Local Red were also equally rated with a score of 20. California 19 was next with a score of 12 and Local Black a score of 2. A varietal score represents the difference between the number of persons selecting that particular variety and the number de-selecting it. Thus, a negative score implies more people de-selecting than selecting that variety. The entire data is still being analyzed to give details on the resistance status.

Table 1. Ranking of cowpea traits by extension staff in a training session at Yendi.

Trait	**Selection Score***
Yield (pods/plant, seeds/pod)	37
Maturity period	20
Plant height	18
Resistance to pests - thrips and PSBs	17
Seed/pod size	11
Growth habit	9
Biomass	3
Color of pod	2
Resistance to drought	1
Uniformity	1

*Difference between the number of times the trait or its components were selected and de-selected.

1.A.2.b.(1)(j) Current status of research: Field insect pests are the major constraint to cowpea production in Africa and they are a major constraint to cowpea production in the United States. Breeding for resistance to insect pests is difficult but host plant resistance is the most promising solution to this problem from economic and environmental standpoints. Cowpea varieties have been developed with resistance to some Insect pests but much remains to be done and this should be a major component of the research conducted by this CRSP.
1.A.2.b.(1)(k) Documented impact: The values of cowpea varieties Melakh and Mouride already have been established and part of their value results from their resistance to certain insect pests.

I.A.2.b.(2) Activity #2: Determine the genetic relationship of new sources of resistance to root-knot nematodes.
I.A.2.b.(2)(a) Priority: (2) Essential
I.A.2.b.(2)(b) U.S. researchers: Hall, Ehlers and Roberts (UCR)
I.A.2.b.(2)(c) HC researchers: None
I.A.2.b.(2)(d) Methodology: World-wide, genetic resistance to root-knot nematodes depends on one dominant gene with two resistant alleles (*Rk* and Rk^2) and a recessive gene (*rk3*). New unique sources of resistance and combinations of resistance genes are needed to enhance the durability and effectiveness of nematode resistance. Allelism tests would be conducted to determine if five recently identified new sources of resistance are genetically unique among themselves and to gene *Rk*. We also would attempt to combine resistance genes to obtain greater and more durable forms of resistance. Populations would be developed from crosses among *Rk* and *rk3* genotypes and newly identified lines. Nematode reproduction (egg mass counts) on cowpea roots with plants in growth pouch tests would be used to evaluate populations for the presence of resistant and susceptible plants in comparison with parental lines.
I.A.2.b.(2)(e) Anticipated (1 year) results of activity: Identify new genetic loci for nematode

resistance and explore the possibility for enhancing resistance by combining genes.

I.A.2.b.(2)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Varieties with multiple genetic factors for root-knot nematode resistance could be developed that would eliminate yield losses from these nematodes and be valuable components of crop rotations designed to reduce nematode pests. Multiple genetic factors should provide broad-based, durable resistance	Two years	Different, stronger sources of resistance to root knot nematode discovered in cowpea

I.A.2.b.(2)(g) Budget:

UCR $\underline{\$6,000}$
Total (Direct costs only) $6,000

1.A.2.b.(2)(h) Major changes: None

1.A.2.b.(2)(i) Progress during past year–UCR, California Experiments: We conducted allelism tests on eleven new sources of resistance that we had identified through recent extensive germplasm screening in both field and growth pouch tests. These eleven new sources of resistance to root-knot nematodes included: breeding lines from IITA and accessions from Botswana, Kenya, Niger, and Australia. In addition, breeding line 96-11-27, developed at UC Riverside, is a potentially unique source of resistance (Table 1) because it has wild cowpea parentage (from *Vigna unguiculata* ssp. *pubescens*). Each resistance source was crossed to UCR 430 which possesses very strong resistance due to Rk^2 (Table 1), and to CB46 which possesses moderate resistance (Table 1) due to *Rk*. The F_1 generation was grown out and allowed to self to produce the F_2 generation. For each of the eleven F_2 populations of the cross UCR 430 x new source, 100 F_2 individuals were screened in pouches for resistance to *Rk*-avirulent *Meloidogyne incognita*. Resistance was quantified based upon the number of nematode egg masses that developed on roots with a lower number indicating higher resistance. The presence of susceptible recombinants among the 100 F_2 individuals with large numbers of egg masses would indicate that genes controlling resistance in UCR 430 and the new source of resistance were different. Unfortunately, no susceptible recombinants were found in any of the F_2's. However, we did appear to identify a new allele on the *Rk* locus, since recombinants with only moderate resistance were observed in one of the F_2 populations, (UCR 430 x UCR 1742). The moderate resistance to *Rk*-avirulent *M. incognita* was similar to that observed in the parental line UCR 1742. This line had an unusual phenotype in that it had strong resistance to *M. javanica* (Table 1) but moderate resistance to avirulent *M. incognita*. A combination we had not seen before. This putative allele may not have practical significance since, overall, it may be less effective than allele Rk^2, but this information further supports the notion that the *Rk* locus is a complex locus with multiple alleles.

We also developed populations to test whether Rk^2 can be combined with *rk3* by crossing CB27 (*RkRkrk3rk3*) with UCR 430 ($Rk^2Rk^2Rk3Rk3$). The F_1 was grown out and shelved to obtain F_2 seed. 150 F_2 individuals were tested in pouches for resistance to *M. javanica*. Interestingly, 17 of the 150 F_2 individuals had greater resistance than plants of UCR 430 suggesting that they are genotype $Rk^2Rk^2rk3rk3$ or $Rk^2rk^2rk3rk3$ and that the *rk3* allele is enhancing the level of resistance to *M. javanica* with the Rk^2Rk^2 genotype as it does for the *RkRk* genotype (refer to CB27 in Table 1). Note that these individuals have the strongest resistance to this nematode that we have detected to date. To try to confirm this result, F_3 families derived from each of the 17 F_2 plants are being tested for resistance to *M. javanica* in a pouch test.

We are transferring the *Rk^2* allele from UCR 430 to a large-seeded blackeye background. In pouch tests, blackeye breeding line 00-11-1430 had very strong resistance equivalent to that of UCR 430 and line 00-11-1518 had strong resistance (Table 1). These lines may be useful as blackeye cultivars as well as being sources of strong resistance with desirable agronomic traits. Seed of these lines was increased in a greenhouse to permit further agronomic evaluation in 2002.

UCR tested the nematode resistance of varieties and breeding lines developed by the Bean/Cowpea CRSP programs in Cameroon, Ghana, and Senegal, as well as breeding lines developed at UCR and some IITA lines (Table 1). A UCR snap-pod type cowpea (UCR 193) and an important IITA line bred at Kano (IT89K-288) had very strong resistance to *M. Javanica*. Cameroon breeding lines 7-29, 12-58, and 7-38 had very strong to strong nematode resistance. In contrast, Cameroon varieties Vya, 2-38 (CRSP Niebe), 24-130 (Lori Niebe) and some sublines of sweet cowpea 24-125B were very susceptible as were Mouride and Melakh from Senegal. Ghana varieties ItxP148 and B22xVal had moderate resistance that was similar to that of *Rk* genotype CB46.
1.A.2.b.(2)(j) Current status of research: This research began at UCR in the 1980's and has been successful in that the new cowpea variety developed by the project for use in California, CB27, has stronger and broader based resistance to root knot nematodes than other cowpea varieties available for California (Table 1). More progress can be made, however, in that UCR has discovered even stronger sources of nematode resistance and they are being incorporated into the next generation of dry grain and cover crop cowpea varieties for the United States (e.g. blackeye-type line 00-11-1430 in Table 1). Studies at UCR also have shown that while a few of the cowpea varieties used in Africa and a few of the breeding lines developed by IITA have strong resistance to root knot nematode most do not. The extent to which root-knot nematodes are a current or potential future problem for cowpea production in Africa has not been quantified. Since most of the obvious symptoms of damage by root-knot nematodes occur on the roots and are underground, they usually are not detected by farmers or scientists and the extent of the problem is underestimated. Studies are needed to quantify the extent to which root-knot nematodes are damaging cowpea and associated crops in different parts of Africa and in different cropping systems.
1.A.2.b.(2)(i) Documented impact: None

I.A.3. Research area: Complete evaluations of advanced lines and increase seed of new cowpea varieties.

I.A.3.a. Background: Support is needed to allow for final evaluations, development of release protocols and publications, and seed increases of several varieties developed by CRSP programs. This will ensure timely release of new varieties and provide adequate supplies of breeders and foundation seed to ensure effective extension to farmers.

I.A.3.b. Proposed research area workplan and subsequent annual progress report:

I.A.3.b.(1) Activity #1: Complete evaluations of advanced lines, prepare release protocols

and publications and increase seed of new cowpea varieties.
I.A.3.b.(1)(a) Priority: (1) Essential
I.A.3.b.(1)(b) U.S. researchers: Hall, Ehlers, Murdock
I.A.3.b.(1)(c) HC researchers: Cisse, Denwar, Ntoukam
I.A.3.b.(1)(d) Methodology: In SARI Ghana, two varieties have been provisionally approved for release, ITP-148-1 and Sul 518-2, depending on their essential amino acid composition. Grain of the two lines have been provided to the University of Ghana, CRSP project for determining their amino acid composition and to conduct other food quality tests. Once the releases have been approved, publications will be prepared to obtain registration of these varieties in *Crop Science*. Breeders and Foundation Seed of these new varieties will be multiplied. Demonstration plots will be planted in cooperation with the Ghana Seed Inspectorate Division and the Grains and Legumes Development Board to help spread the new varieties throughout the cowpea production areas of northern Ghana. In Cameroon, produce and distribute breeders and foundation seed of Lori Niebe, CRSP Niebe, VYA, BR1 And BR2 for Cameroon and neighboring countries. In Senegal, large quantities of Breeders Seed of Mouride and Melakh will be produced at Bambey. In California, produce Breeders Seed of CB27 and collaborate with the California Crop Improvement Association in producing Foundation and Certified Seed of CB27. UCR will conduct trials with CB27 and the standard California variety, CB46, at normal and narrow row spacing. An on-farm growing and marketing evaluation of CB27 will be continued by selecting farmers who would each produce 20,000 kg lots side by side with CB46 using their best practices and monitoring the relative buyer acceptance and price differentials/premiums. UCR also will determine whether a nematode resistant cover-crop / green-manure type cowpea variety can be released from several candidate lines that are under test at this time. Lines would be evaluated for biomass production during the summer cover crop season and seed production in another experiment during the fall growing season. Organic vegetable growers have expressed interest in this type of cowpea variety to enhance soil fertility, contribute to weed management, reduce soil erosion due to wind and suppress the levels of root knot nematode pests in the soil. Similar types of cowpea varieties may be effective for dual purpose use in the Sahel (hay/grain) or tropical Mexico (green-manure/southern pea).
I.A.3.b.(1)(e) Anticipated (1 year) results of activity: In Ghana, Cameroon and Senegal several tons of seed of several new varieties will be produced. In California, seed of CB27 will be produced and its response to higher density planting will be tested and information on market acceptability will be obtained and progress will me made in developing a green manure/cover crop variety.
I.A.3.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
New cowpea varieties should Increase yields and profits and decrease storage losses enhancing food security and incomes. The cover-crop varieties should reduce root-knot nematode and weed populations and increase soil fertility for subsequent crops grown in rotation with cowpea.	Two years	An adequate level of adoption of the new cowpea varieties by farmers

I.A.3.b.(1)(g) Budget:

IRAD	$ 4,000
SARI	2,500
ISRA	4,000
UCR	8,000
Total (Direct costs only)	$18,500

1.A.3.b.(1)(h) Major changes: None

1.A.3.b.(1)(i) Progress during past year IRAD, Cameroon: Extension of the new CRSP varieties is well underway in northern Cameroon. CRSP scientists Georges Ntoukam and Ousmane Boukar worked with officials of the National Extension Program from the Ministry of Agriculture, with a Non Governmental Organization (Service d'Appui aux Initiatives Local de Développement - SAILD) and with a German development program (Deutsche Gesellschaft für Technische Zusammenarbeit -- GTZ). Via this collaboration, seeds of the new CRSP varieties Lori Niébé and CRSP Niébé as well as seeds of two previously-released varieties were distributed and their performance evaluated by groups of farmers throughout the cowpea growing area. This involved work in thirteen localities in the Far-North province and in nine localities in the North Province of Cameroon. The results showed that Lori Niébé and CRSP Niébé were the highest yielding varieties, with about 2000 kg/ha compared to GLM93 (1500kg/ha) and Vya (1300 kg/ha), the latter two varieties being previously released by IRAD. Seed dissemination and evaluation at numerous sites in northern Cameroon is being continued during the 2001 growing season.

ISRA, Sénégal: A non-governmental organization (PROMONO) aggressively extended Melakh in the Thies, Louga and Senegal river areas during 2000 and 2001 and they have been evaluating the new red/brown-seeded line, ISRA-819.

UCR, California: In 2000, about 6000 kg of seed of CB27 was produced at the UC Shafter Research and Education Center for potential use as foundation Seed. This field was rogued many times to remove off-type plants. The seed was not accepted as foundation seed because it was considered to have had too many off-type plants. From the seed and plant types that were observed in a farmers field that was growing certified seed, it was clear that substantial out-crossing had occurred during an increase of breeders seed at UCR in 1998. Consequently, the seed in the farmers field was not certified. In 2000, about 400 kg of breeders seed of CB27 was produced at the UC Riverside Farm. This field also was rogued several times to remove off-type plants. This breeders seed was used to plant five acres at the Shafter Research and Extension Center in 2001. This planting also did not meet purity specifications of the Foundation Seed Service and was not harvested for foundation seed. UCR planted seed from two single greenhouse grown plants of CB27 during the summer of 2001 in the greenhouse to multiply seed of pure CB27 for use as breeders seed in 2002. Despite these problems of seed purity, UCR continues to get favorable marketing feedback from warehouseman who report that buyers appreciate the grain quality of CB27.

UCR is developing a green-manure/cover-crop cowpea variety for use in rotation by vegetable growers. UCR visually evaluated 70 green-manure/cover-crop breeding lines for biomass production and seed yield using long day (June) and short day (late August) plantings at Coachella in 2000. From these evaluations, UCR identified nine breeding lines that merited further evaluation. These nine lines were planted in June 2001 in replicated trials at UCR and Coachella to determine biomass production under long day conditions, and in an August planting at Coachella in 2001 to evaluate seed yield under short day conditions.

Purdue/IRAD/UCR: A paper has been developed to register the "sweet" cowpea germplasm 'C93W-24-125B' by L. W. Kitch, O. Boukar, J. Ehlers, R. Shade, G. Ntoukam and L. L. Murdock which will be submitted to Crop Science.

SARI/Ghana: At a recent meeting of the National Variety Release Sub-Committee held at SARI on October 17-19, 2001, it was decided that the release of the two cowpea varieties would be considered after the second inspection which should be the crop at the flowering stage during the hot season. In northern Ghana, this is around March/April. Accordingly, plans are advanced to plant the materials at the irrigation site at Golinga in the second week of February 2002 so as to synchronize flowering with peak heat.

I.A.4. Research area: Develop grain quality traits for value-added products and consumer appeal.

I.A.4.a. Background: The Georgia project has shown that all-white breeding lines developed at UCR are suitable for producing flour for 'akara' using a dry-milling technique. Cowpea varieties are needed that combine all-white grain with other desirable characteristics. Green seeded cowpea varieties have been developed by USDA, Charleston. Two recessive genes, *gt* for green testa and *gc* for green cotyledon in dry seed were identified in cowpea by R. L. Fery and O. Chambliss. The combined genotype (*gtgtgcgc*), has a dark green seed that when imbibed in water resembles 'fresh-shell' cowpea**.** Recently, IRAD and Purdue University announced the discovery/characterization of a sweet trait in a cowpea line from Cameroon. The University of Georgia has established that the new variety,CB27, has intermediate levels of sucrose. Development of all-white, dry-green, sweet, and sweet-dry-green cowpea cultivars could increase the value and the consumption of cowpeas in the U.S., Africa and other parts of the world.

I.A.4.b. Proposed research area workplan and subsequent annual progress report:

I.A.4.b.(1) Activity #1: Develop all-white, sweet, green, and sweet-green seeded experimental lines of cowpea for the U.S. and Africa
I.A.4.b.(1)(a) Priority: (2) Essential
I.A.4.b.(1)(b) U.S. researchers: Hall, Ehlers, Murdock
I.A.4.b.(1)(c) HC researchers: Cisse, Denwa, Ntoukam,
I.A.4.b.(1)(d) Methodology: Use backcross breeding method to incorporate the all-white, green and sweet traits into adapted cultivars. UCR will cross the sweet cowpea line from Cameroon (24-125B) with the semi-sweet cultivar from California (CB27) and determine whether it is possible to develop a super sweet cowpea variety. ISRA, Senegal will evaluate F_2 populations of 24-125B x Melakh developed by UCR for their expression of the sweet trait and usefulness in breeding for Senegal. ISRA will continue to develop an improved variety with large all-white grain. SARI, Ghana will evaluate F_2 populations of 24-125B x Sul 518-2 developed by UCR for sweetness and usefulness in breeding for Ghana. SARI has initiated a backcross breeding project to incorporate the all-white trait into Sul-518-2, Bengpla and ITP-148-1 and additional cycles of backcrossing will be conducted. IRAD, Cameroon will further purify and multiply the sweet cowpea line, 24-125B, and determine whether it should be released as a cultivar in Cameroon. UCR will produce large quantities of grain of 24-125B and the control non-sweet line, 24-125A, in Coachella Valley during the fall of 2000 for use in consumer tests by food science projects. UCR will study the inheritance of sweet traits. UCR will breed all-white seeded and green seeded advanced lines for potential release as varieties

for California. Purdue will develop efficient methods for screening for higher sucrose levels in cowpea grain and conduct taste panels to determine consumer perception of the trait.

I.A.4.b.(1)(e) Anticipated (1 year) results of activity: Develop experimental varieties with unique grain quality characteristics for consumer acceptability evaluations.

I.A.4.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
New marketing options and increased price and demand for cowpea	Five years	Cowpea varieties with desired traits developed and widely adopted by farmers

I.A.4.b.(1)(g) Budget:

IRAD	$ 1,000
SARI	1,000
ISRA	1,000
Purdue (Murdock)	16,000
UCR	1,000
Total (Direct costs only)	$20,000

1.A.4.b.(1)(h) Major changes: None

1.A.4.b.(1)(i) Progress during past year-- UCR, California and Purdue studies: Ninety breeding lines with all-white grain were evaluated at Riverside in the summer of 2000. The objective is to produce a variety that can be used for producing flour by dry milling for value-added products such as akara. A local processor, Inland Empire Foods, has expressed an interest in licensing an all-white grain variety. Sixty-four single plant selections were made and in addition six lines were bulk harvested to obtain enough seed for replicated yield tests of the six lines that were conducted in California in 2001. The pedigree of the six lines is [[(Bambey 21/CB88)/H8-8-3]/UCD90151]/CB46. The other 58 lines were developed from crosses between the large white seeded Brazilian variety 'Montiero' and CB27 or CB46. They have exceptional seed size (many have seed size that is larger than the largest-seeded California blackeye variety, CB5), seedcoat quality and whiteness. They were planted at UCR during the summer of 2001and further selections were made. Seed of many of these lines were distributed to cooperating breeders in Senegal, Burkina Faso, Ghana and Nigeria in 2000. Eight crosses were made between selected lines from the 64 single plant selections and California breeding lines during the winter of 2000-2001. The F1's were grown out in the greenhouse during spring 2001, and the F2's were planted at UCR in summer 2001 in 70 single row plots. Selections have been made from these populations.

Persistent-green blackeye-type varieties are being bred by UCR for production in California for use in frozen products. These varieties would be produced using the methods currently used for "dry beans". However, after soaking in water for several hours the grain of these varieties resemble fresh blackeye peas and are thus suitable for inclusion in frozen vegetable products. Breeding cowpeas with green cotyledons and green seed coats has been pioneered by the CRSP project of R. L. Fery and the USDA Vegetable Laboratory in Charleston, SC. Advanced persistent-green breeding lines with both the green cotyledon and green seed coat traits have been developed by UCR after two cycles of backcrossing to California blackeyes. In the summer of 2001 a California farmer grew a strip of two advanced lines in a project to evaluate processing quality. UCR

continued to backcross the best persistent green breeding lines with California cultivars. In 2000-2001, ten crosses were made between four persistent green breeding lines that exhibit very green grain color and five blackeye cultivars or breeding lines. The F1's were grown out in the spring of 2001 in a greenhouse and the F2's were planted in 150 row plots during the summer of 2001. Selections have been made from these populations.
Breeding line C39W-24-125B is a sweet tasting cowpea developed by the CRSP breeding program of IRAD, Cameroon and Purdue University. This line has 6% sucrose compared with the 2% of most cowpea cultivars. UCR has crossed this line with CB27, CB46, advanced persistent green breeding lines, Melakh and Sul-518. Evaluations of sucrose content in a collaborative project with Purdue of F_1, backcross [BCF1 (CB27/C39W-24-125B//C39W-24-125B)], and F_2 generations indicate that the sweetness trait is recessive and may be simply inherited. Seed of F_2 populations of the sweet line x Melakh and Sul-518 were provided to ISRA, Senegal and SARI, Ghana. Backcrosses CB27/ C39W-24-125B //CB27 and CB46/ C39W-24-125B//CB46 were made to incorporate the sweet trait into Blackeye type breeding lines. Twenty BC1F1 plants were grown out from each of the crosses in the greenhouse during the spring of 2001 and the BC1F2 populations were planted in 360 row plots at UCR during the summer of 2001. Selections were made for seed quality and agronomic characteristics and the sucrose content of these selections will be evalueted in collaboration with Purdue.

Progress was made in developing experimental lines that incorporate both the sweet and green traits. Double crosses of the type F1(California Blackeye x Green)/F1(California Blackeye x Sweet) were made, and the double cross F1's were grown out to produce double cross F2 seed. The F2 seed was planted at Coachella in spring 2001, and a selected bulk was made. The F3 bulks were planted at UCR during the summer of 2001 in 100 single-row plots. Selections were made for seed quality and agronomic characteristics and the sucrose content of these selections will be evaluated in collaboration with Purdue.

UCR planted a large seed increase block of four sublines of Cameroonian sweet cowpea C39W-24-125B at the Coachella Valley Agricultural Research Station in August 2000 and August 2001 to produce substantial quantities of grain for seed and for quality tests to be conducted by food scientists. Production from the 2000 planting was distributed to Pat Barnes-McConnel for her project with Minority Farmers in the Southeastern US and to Larry Murdock, Purdue for Food Quality evaluations. The 2001 planting will be harvested in November, 2001.

UCR obtained seed of a sweet cowpea line (KVx61-1) from Issa Drabo, INERA cowpea breeder in Burkina Faso during a trip to that country made by Jeff Ehlers and Phil Roberts in August 2001. UCR has sent a sample of this seed to Purdue for sucrose analysis.

ISRA, Sénégal studies: Some of the populations UCR made by crossing sweet and other cowpeas have been evaluated in Sénégal and found to be very prostrate and have low pod set. Consequently, ISRA has made additional crosses with the sweet line.

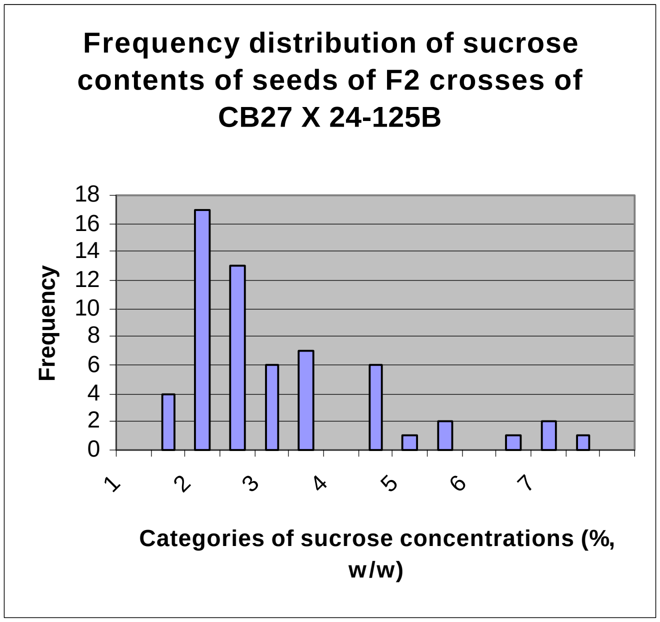
SARI/Ghana studies: Segregating generations of sweet cowpea lines from the University of California-Riverside, were again advanced during the year. However, the procedure and equipment for testing for sweetness are not available and hopefully UC-R would assist. A Number of lines possessing various traits were also received from UC-R for evaluation. These were categorized into all-white/large white, forage type, sweet Cameroonian, California blackeyes, and insect resistant lines for evaluation and transfer of suitable traits to locally adapted varieties. A number of lines were also received from the breeder from the Burkina Faso program. As of now, SARI's facilities for making crosses are dilapidated and exposed to mice invasion. Previous crosses have been destroyed at the podding stage by mice. It is recommended to erect a safe mesh house to enable breeding work to continue.

Purdue/IRAD, Cameroon and UCR, California studies: Genetic Basis of the Sweet Trait in Cameroon Cowpea Line 24-125B. The studies described below began with the discovery that a cowpea line (designated 24-125B) highly preferred by Cameroon farmers due to it's "good taste" or "sweet flavor" (representative comments of Cameroon farmers) has elevated levels of sucrose in the grain. Sucrose analyses carried out by Suzanne Nielsen of Purdue's Dept. of Food Science using both enzymatic as well as HPLC techniques indicated 24-125B had two to three times the sucrose level of typical cowpea lines. Typically, non-sweet cowpea lines have sucrose levels of 1.5-2.5 percent (w/w), while 24-125B showed average sucrose levels of 4-6 percent (w/w). In the early stages of the research, all work was done with samples of 24-125B grown in Cameroon during the 1997 and 1998 seasons. Laurie Kitch, who directed the breeding work in Cameroon with colleagues Ousmane Boukar and Georges Ntoukam that led to the discovery of the sweet line, believed that 24-125B was not fully purified, and contained some off-types. For these reasons, quantitative figures for the sucrose content of 24-125B were considered inexact. There was uncertainty about the quality of the material being analyzed, since different seasons were involved, and it was not known if the environment during the growing season or other factors (e.g., length of time the grain had been stored as well as the type of storage) affected the levels of sucrose. There was, however, no doubt that 24-125B seeds contained substantially elevated levels of sugar.

At this point Jeff Ehlers of the UC/Riverside Hall project brought his breeding skills to the effort and grew out 25 sublines of 24-125B in 1999 from seeds provided by Larry Murdock . Seeds of each of these sublines, together with samples of UC-Riverside-developed CB27 and CB46 were provided, as were seeds of F1's from crosses between 24-125B sublines and CB46. All samples were analyzed at Purdue using a rapid, simple technique for sucrose determination developed at Purdue. Sucrose determinations were done in the blind. Results revealed that seven of the 24-125B sublines had normal levels of sucrose (1.3-2.6 percent, w/w), while the remaining 18 had elevated levels of sucrose (4.3-6.9 percent, w/w). All of the F1's between high sucrose sublines of 24-125B and CB27 or CB46 had low sucrose, suggesting that the sweet trait is recessive.

Ehlers then selected five sublines of 24-125B to multiply, designated 24-125B-1, B-3, B-5, B-9, and B-14. All of these had high levels of sucrose, above 6 percent.

Subsequently, Ehlers grew out the F1 generation of cross CB27 x 24-125B and produced F2 seed. He supplied 60 F2 seeds as well as seed of the original CB27-6 parent and the 24-125B parent to Purdue for determination of sucrose levels. Sucrose levels were determined with the Purdue rapid method, in the blind. The distribution of sucrose contents in the F2 seeds is shown in Figure 1. Clearly there is a strongly skewed distribution in favor of low sucrose content (34 samples out of 60, 2-3 percent, w/w), but with several samples having slightly elevated sucrose (13 samples, 3-4 percent w/w) or moderately high sucrose (9 samples, 4.5 – 6 percent w/w) and 4 samples of the total of 60 having very high levels of sucrose (6.5 to 8 percent).



These results are perhaps consistent with the concept that the sweet trait owes to a pair of recessive genes, but several factors or observations suggest that the sweet trait may be influenced by other factors, too. In the first place, the CB27 parent used in these experiments appears to already have slightly elevated levels of sucrose compared to most other cowpeas – three samples analyzed at the same time as the F2's above had mean sucrose contents above 3.0 percent, w/w (2.88, 3.32, and 3.30). We note that CB27 was also found to have about 3% sucrose by Dick Phillips, whereas CB46 and other cowpeas had levels about 2%. If CB27 itself already has genetically-conditioned slightly elevated levels of sucrose, it may combine with the genetically-conditioned elevated sucrose levels in 24-125B in unpredictable ways; the combination might be additive, subtractive, or multiplicative. Complicating the interpretation still more is the observation that when three seeds of the parent 24-125B samples were analyzed, two had very high levels of sucrose (7.66 and 6.64 percent sucrose, w/w, respectively) but one had a low level of sucrose (2.94 percent, w/w).

Based on these results, it appears that the high sucrose content of 24-125B owes to a small number of recessive genes, perhaps as few as two. If an occasional 24-125B parent used to make the F2's had in fact low sucrose levels, and the other parent contributed one or more genes that caused slightly enhanced sucrose levels but combined in unpredictable ways with the recessive high sucrose alleles from 24-125B, the result might be similar to that seen in Figure 1. Simple experimental error from unreplicated single seed observations might also account for the result.

In a further effort to understand the genetic basis of high sucrose levels in 24-125B, Jeff Ehlers made a series of backcrosses involving selected lines 24-125B-1 and 24-125B-3 and CB27 and CB46 (Table 1).

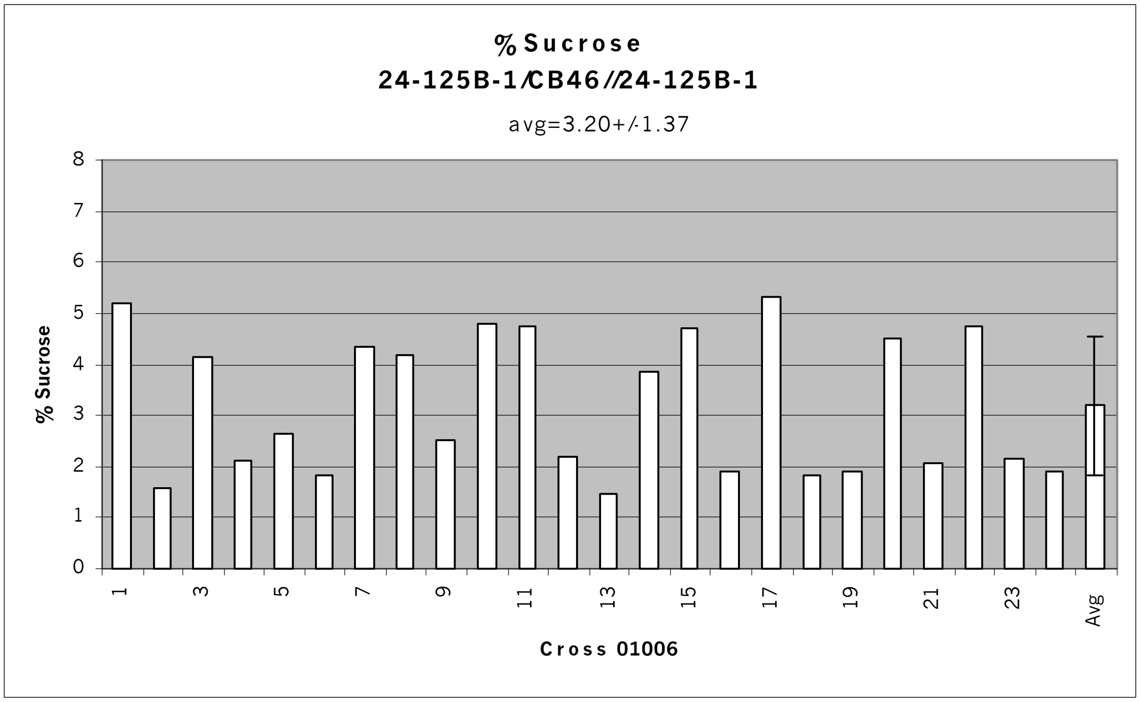
Table 1. Sucrose percentages of BC1F1, F1 and parents.

Parents	No. seeds	Sucrose (%, w/w)
CB27	24	2.26 +/- 0.42
CB46	24	2.21 +/- 0.44
24-25B-1	24	2.99 +/- 1.25
24-125B-3	24	3.16 +/- 0.65
F1 with CB27		
CB27/24-125B-1	20	1.63 +/- 0.24
24-125B-3/CB27	10	2.02 +/- 0.27
F1 with CB46		
24-125B-1/CB46	8	1.43 +/- 0.16
CB46/24-125B-3	8	2.37 +/- 0.16
BC1F1 to Sweet with CB27		
24-125B-1/CB27//24-125B-1	24	3.14 +/- 1.35
24-125B-1/CB27//24-125B-1	24	3.21 +/- 1.27
CB27/24-125B-1/24-125B-1	24	3.68 +/- 1.42
24-125B-3//CB27/24-125B-3	24	3.32 +/- 1.53
CB27/24-125B-3//24-125B-3	24	3.58 +/- 1.45
BC1F1 to Non-Sweet with CB46		
CB46/24-125B-1//CB46	15	1.86 +/- 0.27
BC1F1 to Non-Sweet with CB27		
24-125B-1/CB27//CB27	15	1.62 +/- 0.25

Review of the data indicates the measured sucrose content of the two sweet lines used was unusually low, for reasons that are not clear. This may have been the result of a problem with the newly devised method of sucrose assay, the season or other environmental factors during growth of the plants, or have arisen from a systematic error, such as a problem with the master sucrose standards being too low. Where seeds are available, reanalysis will be carried out to verify the results.

Data from reciprocal F1's suggest that maternal effects are not important for sucrose level. Despite the unusually low sucrose concentrations, inspection of the individual data from the BC1F1 to Sweet with CB27 reveals clearly that there was, as predicted, a bimodal distribution of sucrose contents consistent with two separate recessive high sucrose alleles. This is evident also in the high variances associated with the sucrose contents of these seeds. In both cases where we examined BC1F1s crossed to the non-sweet lines, the sucrose levels averaged about one half as much sucrose as seen with the backcrosses to sweet line, and a much lower variance. In aggregate, 79 of the BC1F1 seeds backcrossed to the sweet lines had "high" sucrose levels while 65 of them had "low" sucrose levels.

A representative result is shown in Figure 2. In this set of analyses, 11 of the seeds assayed had high sucrose contents while 13 of them had low sucrose.



Segregating generations of sweet cowpea lines from the University of California-Riverside, were again advanced during the year. However, the procedure and equipment for testing for sweetness are not available and hopefully UCR would assist. A number of lines possessing various traits were also received from UCR for evaluation. These were categorized into all white/large white, forage type, sweet Camerounian, California blackeyes, and insect resistant lines for evaluation and transfer of suitable traits to locally adapted varieties. A number of lines were also received from the breeder from the Burkina Faso program. As of now, SARI's facilities for making crosses are dilapidated and exposed to mice invasion. Previous crosses have been destroyed at the podding stage by mice. It is recommended to erect a safe mesh house to enable breeding work to continue.

1.A.4.b.(1)(j) Current status of research: In recent years, a cowpea line was discovered by the Purdue/Cameroon CRSP project that has sweeter grain than other cowpea cultivars that have been evaluated. Studies are needed to determine the extent of consumer demand for this trait and to exploit it.

1.A.4.b.(1)(k) Documented impact: Impact will be evaluated by the degree of consumer and farmer acceptance of varieties that have the sweet trait.

Table 1. Resistance to Root-Knot Nematode *Meloidogyne javanica* in Various Cowpea Varieties and Breeding Lines as Determined in Pouch Tests at UCR in 2001.

Variety or line	Origin	Nematode egg masses	Resistance of check lines
		# / root system	
UCR 430	IITA as IT84S-2049	51	very strong
00-11-1430	UCR blackeye-type breeding line	71	
UCR 193	UCR snap-pod type cowpea	86	
IT89KD-288	IITA, Kano	90	
Cameroon 7-29	Cameroon breeding line	94	
UCR 1742	UCR breeding line	102	
Big Buff	Australia and IITA as IT82E-18	120	
00-11-1518	UCR blackeye-type breeding line	122	
Cameroon 12-58	Cameroon breeding line	127	
Cameroon 7-38	Cameroon breeding line	146	
CB27	California variety	146	strong
Iron Clay	U.S. cover-crop variety	189	
96-11-27	UCR breeding line from wild cross	210	
ITxP148	Ghana variety	218	
Cameroon 24-125B-3	Sweet subline	226	
CB46	California variety	229	moderate
B22 x Val	Ghana variety	230	
Cameroon 24-125A	Non-sweet line	250	
Sul 518	Ghana variety	255	
Cameroon 24-125B-5	Sweet subline	262	
Vya	Cameroon variety	267	
Cameron 2-38	Cameroon variety “CRSP Niebe”	282	
Cameroon 24-125B-1	Sweet subline	283	
Melakh	Senegal variety	334	
CB3	California variety	359	very weak
Cameroon 24-130	Cameroon variety “Lori Niebe”	370	
Mouride	Senegal variety	371	

1.A.4.b.(1) Appendix I

Sucrose Assay Protocol: To understand (1) the genetic basis of sweetness (2) the economic importance of the sweet trait in cowpea and (3) to incorporate this trait into new cowpea varieties requires that we be able to accurately quantify it. Early work at Purdue demonstrated that the “sweet” flavor of line 24-125B from Cameroon was due, at least in part, to elevated levels of sucrose. To understand the sweet trait, to estimate its potential value to consumers,
and to develop the trait through plant breeding, required that we have a simple, rapid, and cheap method for estimating sucrose.

Accordingly, at Purdue, a very simple assay was devised that enables interested non-biochemists (breeders, economists) to obtain quantitative measures of the amounts of sucrose present in individual cowpea seeds. The principle of the assay is extremely simple, and the required equipment is minimal, cheap, and readily available, at least in the USA.

The assay principle involves extracting the sucrose in aqueous buffer, converting the sucrose to glucose by adding invertase to the extract, and measuring the resulting glucose using glucose test strips and a glucose monitor of the type used by diabetics to measure their blood sugar.

The sucrose assay is currently being used in pilot studies (late summer, 2001) by Madame. Mbene Faye to measure sucrose levels in cowpea seeds collected at local markets in Senegal. We anticipate that modifications of the protocol will be required based on experience.

The simple sucrose assay has been compared extensively with a much more sophisticated, expensive, and complicated HPLC method. When extracts of 23 separate cowpea seeds with sucrose contents ranging from 2-6 percent were analyzed simultaneously by the HPLC and glucose monitor techniques, the correlation coefficient (R-square) value was 0.92.

Sucrose Assay Protocol--Materials and Equipment Required: Commercially available glucose monitor (about $30), glucose test strips, small mortar and pestle, a supply of 1.5 ml plastic Eppendorf tubes, distilled water, pH meter or pH test strips, small graduate cylinders, quantitative pipetters that can deliver up to 2.0 ml (e.g. Pipetteman), a balance that can weigh to the mg level, preferably to 0.1 mg., 100 ml and 50 ml volumetric flasks, water bath or heating block to enable samples to be heated to 55 deg C.

Reagents: sodium acetate, acetic acid, sucrose as standard, glucose as a standard, invertase (100 mg/ml pH 4.5 sodium acetate buffer, see below).

Solutions: The sucrose extraction buffer is made up at 50X its final concentration. It is a 1M solution of sodium acetate, pH 4.7. Prior to using it, it must be diluted. To do this, mix 2ml of the 50X stock with 98ml water. The final concentration will be 20mM sodium acetate and the pH will be 4.5. Use this buffer for extracting the sucrose from cowpea seeds, for mixing the sugars, and for mixing the invertase. Sucrose standard solution, made up in the above diluted buffer at 10 mg/ml, and glucose standard at 5 mg/ml. Sucrose standard: Mix 1gram into a final volume of 100 ml buffer. After incubating with invertase for 35 minutes at 55 C (see below) this should give you a reading of ~500mg/dl or 10%. Glucose standard: Mix .5 gram glucose into 100ml buffer. This takes a long time to dissolve completely. After carrying this through the assay (see below), this should give a reading of 500mg/dl.

Procedure:

1) Weigh individual seeds and record the weight.

2) Grind the seed to a fine powder using the mortar and pestle.

3) Add 10X volume of extraction buffer, e.g., if the seed weighs 0.1g add 1 ml of buffer. Continue to grind for a couple of minutes longer.

4) Pour the slurry into a 1.5 ml Eppendorf tube. Allow the flour to settle, or if you have a centrifuge, spin the sample until the supernatant (aqueous layer above the solid pellet) is clear.

5) Transfer 0.2ml of the clear supernatant into a new Eppendorf tube.

6) Add 10ul invertase stock solution to the 0.2ml liquid (step 5) and incubate at 55 C for 35 minutes. If you don't have a heating block or water bath to get this temperature you can let the reaction proceed for 1.5 hr at room temperature.

7) At the end of the incubation period, place 15ul of the sample (this can instead be a small droplet – the important thing is that you are consistent) onto a glucose strip which has is in position in the glucose monitor (see the monitor user's guide for precise directions).

8) Record the glucose measurement. Units are mg per deciliter (mg/100 ml).

9) % sucrose of the seed = glucose concentration X 0.02.
(e.g., a glucose reading of 250mg/dl = 5% sucrose content of the seed).

10) For each group of seeds analyzed, several blanks or controls should be carried along. These should include (i) testing multiple dilutions of the sucrose stock solutions – to verify that the invertase is active and that the expected sucrose concentration are indeed accurately determined, and that the assay is working well. These measurements can be used to plot a standard curve, if desired; (ii) sucrose standards carried though without invertase addition – the glucose monitor should show no glucose to be present; (iii) one or more seed extracts (representative of the batch of seeds) carried through without the addition of invertase – in many seeds, glucose levels are quite low, much lower than sucrose, and often below the limits of detection of the glucose monitor. Still, it may be possible that some seeds have much higher glucose levels than are normally encountered – not enough studies on seeds from different sources have yet been done to be sure.

I.A.5. Research area: Regional IPM development and testing

I.A.5.a. Background:

I.A.5.b. Proposed research area workplan and subsequent annual progress report:

I.A.5.b.(1) Activity #1: Develop alternatives to chemical insecticides
I.A.5.b.(1)(a) Priority: (1) Essential
I.A.5.b.(1)(b) U.S. researchers: Shepard
I.A.5.b.(1)(c) HC researchers: Salifu, Owusu-Akyaw, Ntoukam, Balde
I.A.5.b.(1)(d) Methodology: Timing and rates of neem and other botanical materials such as Hyptis will be tested in farmers' fields and research plots. Because neem is translaminar, applications for thrips control will be tested in experiments that include preventive sprays starting at raceme development. Simplified methods for standardizing rates will be the focus of activities both on experimental farms and in farmers' fields. Additional tests will be carried out to ascertain the effects of neem on natural enemies such as indigenous predators and parasitoids. Tests will be conducted in Cameroon and Senegal of the neem spray approach for controlling flower thrips developed by SARI, Ghana.
I.A.5.b.(1)(e) Anticipated (1 year) results of activity: The experiment will determine the overall efficacy of neem and other botanicals to insect pests.
I.A.5.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Higher cowpea yields and lessened impact on the environment and to farmers' health	2-5 years	Surveys and observations that show farmers using botanical materials rather than chemicals

I.A.5.b.(1)(g) Budget:

IRAD	$ 1,000
CRI	2,500
SARI	4,500
ISRA	1,000
Clemson	5,000
Total	$14,000

I.A.5.b.(1)(h) Major changes: No major changes occurred in the approach relative to the work in Charleston. In Ghana, however, Crops Research Institute evaluated commercial formulations of neem (Neemazal and Neemol). The rationale was that farmers were disinclined to make their own preparations.

I.A.5.b.(1)(i) Progress during past year: Research Activity -- Anti-feedant effects and toxicity of neem to *Nezara viridula* (L.): Laboratory tests. (M. Abudulai and M. Shepard).

There is a large body of literature relative to the anti-feedent and growth-inhibiting properties of neem on insects. In Ghana, neem trees are abundant and widely distributed. Farmers in Northern Ghana have had success with crude extracts from neem leaves and seed kernels. However, field efficacy against insect pests is sometimes inconsistent. More refinements in the extraction, formulation and application are needed before the material is recommended as a part of an integrated approach to the management of cowpea pests.

In the U.S., a commercial formulation Neemix repels sucking bugs and kills nymphal bugs and causes deformities in adults. Applications in the field significantly reduces pod feeding by the sucking bug complex.

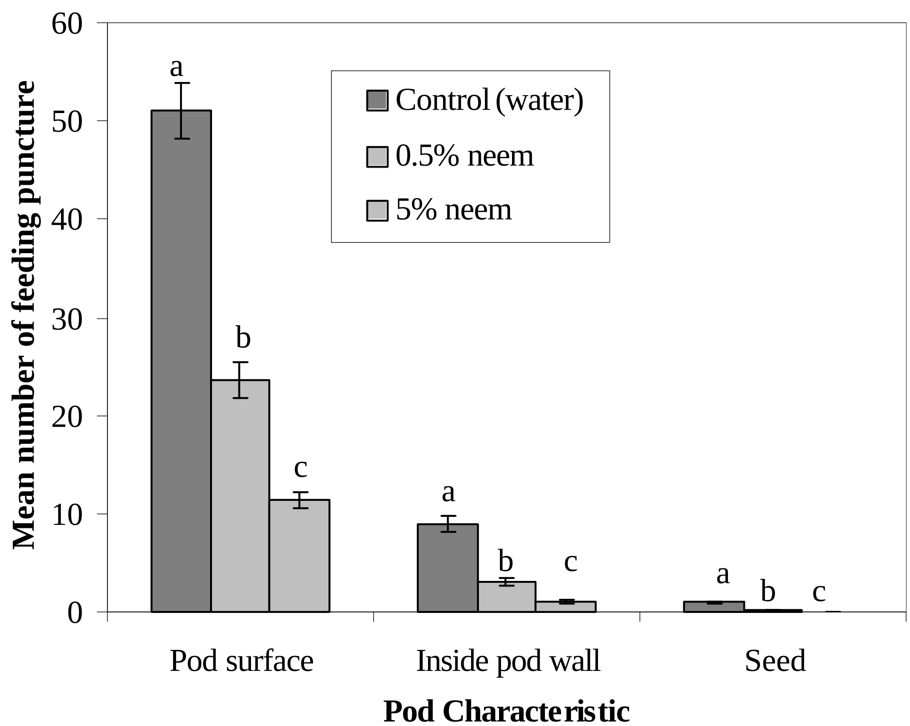
Methods and Materials -- Anti-feedant Tests: Two concentrations (0.5 and 5%) of Neemix (from Matsui Corp.) were tested for anti-feedant properties against the southern green stink bug, *Nezara viridula*. Cowpea pods were treated by dipping them for 30 seconds (s) at each concentration. Pods dipped in distilled water served as controls. Pods were allowed to air dry for about 30 m then presented to *N. viridula* adults for 48 h. Adult bugs, two-days old or older, were starved for 24 h before the experiment. *N. viridula* were placed singly into plastic crispers (11 by 8.5 cm) containing treated or water-treated controls. Twenty *N. viridula* of equal number of males and females were used per treatment and were replicated three times.

Feeding damage to pods was determined by the acid fuscin test. Stained pods were rinsed in water and examined for cone-shaped salivary deposits or stylet sheaths that indicate feeding. Feeding punctures on the outer surface of pods, inner wall and the developing seeds were counted.

Toxicity Test: Neemix was diluted serially in distilled water to aqueous concentrations of 0.1, 0.5, 1.0, 5, and 20%. One day-old 4th instar *N. viridula* were used by dipping them for one second (s) in the appropriate neem solution. Nymphs dipped in distilled water served as controls. Ten nymphs were used for each neem concentration and control. The treated and control nymphs were left to dry for 20 m then held in plastic containers (19 cm x 13.5 cm) and observed until they died either as nymphs or adults. The bugs were fed green beans, and water provided by a wick in a plastic container. The test was replicated three times. Deformities and time required for molting to adults were noted. Fecundity and longevity of adults also were recorded.

Results and Discussion -- Anti-feedant Test: Treatment with neem significantly ($P < 0.05$) reduced pod feeding by *N. viridula* compared to the control (Figure 1). Mean numbers of feeding punctures on pod surfaces, inside pod walls and on seeds were significantly ($P < 0.05$) fewer at 5% than at 0.5% neem concentration, which clearly showed that the anti-feedant activity was dose dependent.

Figure 1. Effect of neem on cowpea pod-feeding by *N. viridula.* Bars within each pod parameter with different letters are significantly different ($P < 0.05$, *LSD* test). Data for 1999 and 2000 combined for a total of six replications.



Toxicity Tests: The LC_{50} and 95% CL for mortality of *N. viridula* was 1.8% (0.83-4.18) 5 days after treatment of nymphs. Nymphs treated with neem solutions at 1.0% and higher rates died as fourth instars. Lower concentrations caused morphological defects in nymphs that molted to fifth instars or adults. Neem-treated adults developed deformed wings and scutella. In addition, neem treatments significantly increased development time to adults and reduced longevity (Table 1).

Table 1. Effect of neem on *N. viridula* development, longevity and fecundity. Charleston, SC.

*Conc. (%)	% molts to 5th instar	% adult emergence	% deformed adults	Adult development Time (d)	Longevity (d)	# eggs per female/d
Control	90.0 ± 5.8a	76.7 ± 12.0a	4.8 ± 4.7b	13.1 ± 2.6b	32.3 ± 6.8a	123
0.1	50.0 ± 5.8b	23.3 ± 8.8b	83.3 ± 16.7a	15.5 ± 3.3a	7.0 ± 1.2b	0.0 ± 0.0
0.5	33.3 ± 13.3bc	6.7 ± 3.3bc	100.0 ± 0.0a	15.9 ± 3.0a	-	-
1.0	13.3 ± 3.3c	0.0 ± 0.0c	-	-	-	-
5.0	-	-	-	-	-	-
20.0	-	-	-	-	-	-

Research Activity: Field evaluation of neem for reduction of *Nezara viridula* (L.) feeding in cowpea (M. Abudulai and M. Shepard.

Methods and Materials: There were two treatments consisting of 0.5% aqueous neem and water control. The 0.5% aqueous neem contained 225 ppm Azadirachtin at final dilution. Foliar sprays were applied at four days intervals for a total of 3 times using a tractor mounted spray boom (5.5 m swath width). Plants were sprayed to run-off. Cowpea cultivar 'Pink-eye Purple Hull-BVR', which is susceptible to pod-sucking bugs (PSB), was planted on 27 June 2001 in field plots laid out as randomized complete block design with four replications. Treatments were first applied near early pod-fill because cowpea is most susceptible to stink bug damage at this stage. Densities of *N. viridula* were determined before each spray and 24 h afterwards using the "sight-count" method. Insect samples were taken at random in two 4-m rows of each plot between 0700 and 0900 Eastern Daylight Saving time.

At maturity, pods were harvested from 6-m of the two center rows of each plot and data were taken on pod and seed damage as well as seed weight, number of seeds per pod and yield. Shriveled pods and seeds or seeds that were decayed or having visible stink bug feeding scars were considered damaged by *N. viridula*. Data were analyzed using paired *t*-test ($P < 0.5$) to compare means.

Results: Significantly lower pod and seed damage were recorded in the neem-treated plots than in controls (Table 2). Number of seeds per pod and yield also were significantly greater in the neem treatments compared with controls. However, no significant difference was detected between the treatments in the 100 seed weight.

Table 2. Effect of neem on damage by pod-sucking bugs and yield of cowpea. Charleston, SC.

Treatment	# seed/pod	100 seed wt (g)	% pod damage	% seed damage	Yield Kg/ha
Neem-treated	10.7 ± 0.3a	16.2 ± 0.3 a	25.6 ± 4.1 b	11.5 ± 0.7 b	1212.0 ± 25.6 a
Control	8.8 ± 0.2b	15.9 ± 0.1 a	64.5. ± 3.2 a	24.1 ± 3.6 a	887.4 ± 64.3 b
P value for *t*-test	0.0022	0.5322	0.0001	0.0351	0.0126

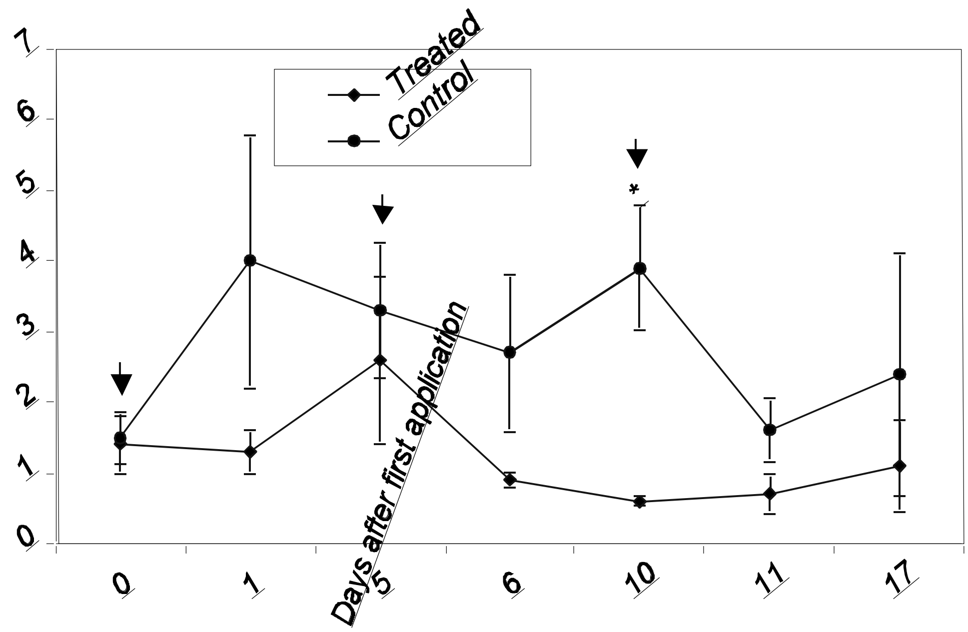


Figure 2. Effect of field applications of neem on densities of *N. viridula*. Neem applied during podding stage. Asterick (*) indicates date with significantly ($P < 0.05$) lower numbers of pod sucking bugs in the neem-treated plots. Arrows indicate days of pre-spray sampling and neem application date. Charleston, SC.

N. viridula populations declined in all neem-treated plots but a significant difference was only detected between treated and control plots at 10 d after the first spray (Figure 2). This date coincided with the peak bug density. Increase in numbers of bugs just before the second spray in treated plots was a result of nymphs hatching from eggs. In summary, the major action of neem was reducing damage to pods and seeds and not necessarily direct mortality of stink bugs. This reduction in damage translated to increased cowpea yields. Deformed stink bug adults were observed in the neem-treated plots.

Research Activity: Effect of neem on *T. basalis* oviposition in the laboratory (M. Abudulai and M. Shepard).

Methods and Materials: Egg masses were surface-treated using a pipette to deposit 1ml of a 0.5% neem solution or distilled water. A small camel-hair brush was used to spread the droplet over the entire surface of the egg mass. After 2 h of drying at room temperature, egg masses were then glued (Elmer's Glue-All, Borden Inc., Columbus, Ohio) to strips of index cards (2 x 4 cm). The choice test included, a neem-treated and a distilled water-treated egg mass glued to the same piece of cardboard. For the no-choice test, either a neem-treated or water-treated egg mass was placed into the test container. There were 10 replicates for each treatment in both tests. One mated female *T. basalis,* 2-3 days after emergence*,* was transferred into each petri dish (10 x 1.5 cm) containing a single egg strip, using a small camel-hair brush. The wasps were allowed to oviposit for 24 h. A cotton roll moistened with 80% honey solution was provided as food for the parasitoids.

Results: Treatment of host eggs did not affect *T. basalis* oviposition in those eggs under choice and no-choice conditions (Table 3). In addition, neem treatments did not affect parasitoid development or emergence. Additionally, treatment of host eggs during pupal stage of *T basalis* did not significantly affect its emergence.   Parasitoid emerged from host eggs after 10 d of parasitization.

Table 3. Laboratory evaluation of the effect of neem treatment of *Nezara viridula* egg masses on *Trissolcus basalis* parasitization and emergence.

	Choice Test		No-choice Test		Eclosion Test	
	Parasitized	Emerged (%)	Parasitized	Emerged (%)	Parasitized	Emerged
Treated	26.4 ± 7.4	53.2 ± 12.5	43.5 ± 4.8	78.6 ± 2.9	22.2 ± 3.8	74 ± 7.5
Control	19.3 ± 5.4	43.8 ± 9.4	57.2 ± 6.4	83.8 ± 4.3	32.5 ± 8.1	82 ± 3.2
P value for *t* test	0.4440	0.5568	0.0974	0.3170	0.2739	0.3740

Research Activity: Impact of neem on parasitism and predation on egg masses of *Nezara viridula* in cowpea following augmentative releases of the parasitoid, *Trissolcus basalis* (M. Abudulai and M. Shepard)

In addition to understanding the effects of neem on the target pest, it is important to know how the material may affect natural enemies. This study was designed to assess the impact of neem on *Trissolcus basilis*, the major parasitoid of *Nezara viridula* eggs. The effects of neem on predation on *N. viridula* egg masses also was determined.

Methods: An augmentative release (3,280 wasps/hectare) of *Trissolcus basalis* (Wollaston) was made in cowpea on August 21, 2000, after placing egg masses of *N. viridula* in the field. Parasitoids were released midway between adjacent neem-treated and untreated plots in the evening around 1830 Eastern Daylight Saving time. The parasitoids were released by placing parasitized *N. viridula* egg masses in the field. Twenty unparasitized egg masses were placed in each plot, 5 in each cardinal direction from the parasitoid release point. Treated plots were sprayed with 0.5% aqueous neem solution.   Untreated plots served as control. Egg placement and parasitoid release were carried out one day after spray application. Treatments were replicated four times. Egg masses were examined in the field for attacks by predators and all remaining eggs were collected seven days later, brought to the laboratory and held until parasitoids emerged.

In addition to the above study, neem-treated and water-treated control egg masses were placed on opposite sides of plants by stapling the cardboard containing the egg mass to the under surface of leaves. Ten pairs of egg masses were placed in each plot. There were four replications. The eggs were examined in the field for attacks by predators. After seven days, remaining eggs were collected, brought to the laboratory and held until parasitoids emerged.

Results: In the augmentative release study, *T. basalis* dispersed equally from the release point into treated and untreated plots with no apparent preference for direction. Average number of egg masses parasitized out of 20 egg masses per plot was 6.0 in treated plots and 7.5 in control. However, the removal of eggs by predators affected the rate of parasitization by *T. basalis*. In addition to *T. basalis*, an unknown parasitoid, possibly an *Oencyrtus* sp., was reared from the field exposed eggs. Percent parasitism and emergence of parasitoids were not significantly different between treated and untreated plots (Table 4). Likewise, predation on the egg masses was similar in treated and control plots. Fire ants were the major predators observed preying on eggs in the field. Other predators in the field included earwigs, gryllids and coccinellids. Earwigs were the most abundant predators recorded from pitfall traps.

Field tests using sentinel plants (=those with egg masses attached to them) to ascertain possible effects of Neem on susceptibility of egg masses to attacks by natural enemies revealed that neem treatment did not affect susceptibility of egg masses to parasitism or predation (Table 4).

Table 4. Parasitism and predation of *N. viridula* egg masses after augmentative release of the parasitoid, *T. basalis*.

	Augmentative Release			Field Choice Test		
	Percent	Percent	Percent	Percent	Percent	Percent
Neem-treated	**16.2 ± 2.1**	**34.0 ± 2.1**	**33.5 ±** 9.6	**23.7 ± 1.0**	**37.6 ±** 2.8	**26.2 ±** 7.6
Control	15.5 ± 1.4	46.7 ± 13.1	26.9 ± 4.0	24.4 ± 2.1	33.4 ± 3.8	26.9 ± 5.8
P value for *t*-test	0.8141	0.3792	0.5493	0.7967	0.2786	0.8761

Field tests of the efficacy of commercial formulations of neem for control of cowpea insect pests in Ghana (M.Owusu-Akyaw and J.V.K. Afun, Crops Research Institute, Kumasi, Ghana)

Methods: These tests were carried out during the minor season at Kwadaso, Forest Zone, in Ghana. Some farmers had complained that preparation of neem extract from trees was too laborious therefore commercial preparations of neem, sold as Neemazal (0.15% azadirachtin), was used in these tests. Randomized replicated trials were carried out during both the minor season, 2000 and the major season, 2001. Data on aphids, thrips, *Maruca* pod borers, pod-sucking bugs and yields were taken.

Results: Based on data from two seasons, the commercial formulation of neem (Neemazal) was not effective against any of the insect pests tested. Cowpea yields were doubled when the commercial insecticides Karate and Dimethoate were used compared to yields from the neem-treated plots. However, in one test, damage by sucking bugs was significantly lower than that in untreated plots. It was clear that this commercial formulation was not effective at the rates used. It may be that the concentration of neem used in this test was too low. In addition, it is generally known that neem formulations have a finite shelf life so the material may have been stored too long before using. Development of appropriate technology that could be implemented by local farmers for preparation and use of neem would greatly improve its efficacy.

Research Activity: Evaluation of efficacy of *Hyptis specigera* for controlling thrips and pod sucking bugs of cowpea.

Hyptis spicigera occurs commonly as a noxious weed in impoverished soils. In areas of North Ghana, it is also commonly referred to as "mosquito medicine" due to its pungent repellence properties against mosquitoes. Some farmers have also often indicated that they exploit this plant in storing grain commodities. Studies at the University of Ghana to examine extracts of *H. spicigera* for activity against *Musca domestica* and *Periplaneta americana* indicated significant knockdown effects.

The experiment was a 5 x 5 Latin Square Design with plots size of 4 rows 3 m long. Spacing was done at 60 cm between rows and 20 cm between hills. Treatments included aqueous extracts of Hyptis @ 20%, 40%, 60% respectively, pyrethroid and water (control). Concentrations of Hyptis were based on weight/volume while the extracts were applied with a knapsack sprayer. Field randomization of treatments was as shown below:

	C1	C2	C3	C4	C5
R1	Water	20%	40%	60%	Pyrethroid
R2	20%	60%	Water	Pyrethroid	40%
R3	40%	Pyrethroid	20%	Water	60%
R4	60%	40%	Pyrethroid	20%	Water
R5	Pyrethroid	Water	60%	40%	20%

Data to be recorded thrips included visual rating (on a 1-5 scale increasing damage) of 5 consecutive plants within the row for thrips damage at 7 days after imposition of treatments. Estimates of pod sucking bug damage-shrivelled pods and punctured seed were also compiled on a 500-seed basis.

Treatment	Thrips populations/flower before and after spraying		Thrips damage rating (1-5)	PSB damage (%)	Grain yield (kg/ha)
	Before	After			
Water	13.2	19.7	4.3	48.9	487.8
10% Hyptis	1.7	5.6	3.0	25.0	1291.1
20% Hyptis	2.9	6.2	3.1	46.1	1181.4
40% Hyptis	3.5	5.1	2.5	40.2	1188.0
60% Hyptis	4.4	1.8	2.0	31.5	1301.4
Pyrethroid	3.4	1.5	1.5	23.8	1434.5
LSD @ 5%	--	--	1.1	13.3	155.0

Research Activity: Cowpea insect control in Cameroon with neem(George Ntoukam, IRAD, Cameroon).

Methods: Neem trials were carried out on research plots at the IRAD-Maroua Station during the 2001 growing season. The neem protocol followed was that being promoted by PRONAF – developed by A.B. Salifu (SARI). Experiments were carried out on plots of the sweet cowpea (24-125B).

Results: Data has been collected on insect counts and yield measurements and although data have not yet been analyzed because harvest coincided with the end of the CRSP fiscal and reporting year, preliminary observations indicate that neem treatment provided substantial plant protection and the technology will be expanded next year if resources are available. Systematic evaluation of the data for this year will be carried out when the cowpea harvest in Cameroon is completed.

I.A.5.b.(1)(j) Current status of research: This work began in Ghana about four years ago. We have worked with neem on cowpea in Charleston for about four years. In Ghana, particular attention should be given to an organized way to extract and formulate and apply the material so that quality control is maintained. This seems to be a major constraint. If selected farmer leaders or farmer cooperatives, NGOs, or others could be organized to do this, then better quality control could be gained. Another possibility would be to hold "farmer field schools" on the extraction, formulation and testing of neem for trees. The use of formulated products should be discouraged because neem does not store well. I would anticipate that all this could be done within the next three or four years. This could put a system in place as part of IPM through Training of Trainers (TOT) and Farmer Field Schools (FFS).

I.A.5.b.(1)(k) Documented impact: Developing alternatives to chemical insecticides will have a major impact on cowpea production in West Africa. The challenge always has been to take advantage of the newer, high-yielding varieties but these are almost always more susceptible to larger insects like pod-sucking bugs and Maruca pod borers. Neem, the botanical insecticide/anti-feedant, has been shown to significantly improve cowpea yields. The trees are readily available as a source for extraction of the active principle. In carefully control studies, and in farmer field schools neem applications have been shown to increase yields. Laboratory tests confirm the anti-feedant properties and growth disrupting characteristics of neem. The material also could play a major role in preventing infestations by cowpea weevils in stored cowpea.

Conservatively, when techniques have been developed for extraction, formulation and application of neem (and possibly other botanical materials), cowpea yields in West Africa could easily be increased by at least 20%.

I.A.5.b.(2) Activity #2: Establish relationships between pest insect density and cowpea damage and yields.

I.A.5.b.(2)(a) Priority: Essential

I.A.5.b.(2)(b) U.S. researchers: Shepard

I.A.5.b.(2)(c) HC researchers: Salifu/Owusu-Akyaw

I.A.5.b.(2)(d) Methodology: Botanical materials will be applied during different growth stages of the cowpea plant. This will be carried out in experimental plots and as demonstrations in Training of Trainers/ Farmer Field Schools.

I.A.5.b.(2)(e) Anticipated results of activity: Relationships established between key insect pest population densities and damage/yield of cowpea.

I.A.5.b.(2)(f) Anticipated impact to which this activity will contribute, time frame indicators:

IMPACT	TIME FRAME	INDICATOR
Reduced chemical insecticide use. Better understanding of insect pests and densities at which significant damage can be expected	3-5 years	Comparison of baseline data from farmers who have not participated in the exercises with farmers using action levels as a basis for intervention

I.A.5.b.(2)(g) Budget:

CRI	$2,000
SARI	3,000
Clemson	4,000
Total (Direct costs only)	$9,000

I.A.5.b.(2)(h) Major changes: This activity is focused on cowpea damage/yields insect density relationships. The use of the term "economic thresholds" is not appropriate since little is known of the economics that vary for within and between regions. However, knowledge of the insect damage/density relationships can help farmers make informed decisions about whether or not interventions are necessary.

Because it is not possible to predict levels of insect infestations in the field, artificial removal of flowers and pods at different stages of plant development provides information about the cowpea plant's ability to compensate for damage to these plant parts. Thus, field research at Charleston this year focused on observing gross responses of the cowpea plant to removal of blooms and pods.

I.A.5.b.(2)(i) Progress during past year: Research Activity -- Influence of bloom and pod removal on yield of cowpea (M. Abudulai and M. Shepard).

It is recognized that artificial removal of plant parts does not precisely simulate the action of pests. However, hand removal of plant parts can provide insights into the gross response of cowpea plants to attacks by insect pests.

Methods: Bloom and pod removal tests were conducted in two tests during the summer. Test 1 was planted on 17 June and Test 2 on 27 June 2001. Bloom and pod removal treatments in Test 1 comprised removing blooms for 10 or 20 continuous days from bloom initiation, removing pods at 10 or 20 d after bloom initiation. No blooms or pods were removed in control plots. Only open flowers were removed. In test 2, less severe bloom and pod removal treatments were imposed. Bloom removal was carried once at peak flowering on 11 August at levels of 20, 50 and 80%. Pod removal treatments were imposed at beginning of seed development in pods on 13 August at levels of 20, 50 and 80%. Percent plant part removal was determined by counting the number of flowers or pods and randomly removing the appropriate number of flowers or pods from10 plants in 1 m row with 0.91m spacing. The cowpea cultivar,'Pink Eye Purple Hull – BVR' was used in both tests. Endosulfan was applied weekly to control pod-sucking bugs in the field. All treatments were replicated six times.

Results: Removal of 10% of the blooms for 10 days did not affect yield (Table 5). However, when blooms were removed for 20 continuous days, yields were reduced 57%.
Pod removal for 10 and 20 days reduced yields by 50% and 85%, respectively. Bloom removal at 20, 50 and 80% did not affect yields in Test 2 (Table 6). Bloom removal at 20%

and 50% did not reduce the number of pods produced relative to control. The cowpea plant was more sensitive to pod removal than to removal of blooms. All pod removal treatments (10, 50 and 80%) significantly reduced yields compared to controls. Pod weight was significantly lower in the 80% pod removal treatment relative to the other treatments and control. In summary, removal of blooms (which could simulate attacks by thrips or Maruca pod borers) during early blooming, would not be expected to affect yields but continuous pressure on blooms for 20 days reduced yields. Removal of pods at all levels negatively impacted yields.

Table 5. Effect of bloom and pod removal on yield of cowpea. Charleston, SC. **Test 1.**

Treatment	# Pods/plant	Wt (g)/pod	100 Seed wt (g)	# Seed/pod	Yield/plant (g)
Control	9.1 ± 1.0a	1.9 ± 0.1a	15.4 ±0.1a	10.1 ± 0.3a	14.0 ± 1.4a
Bloom removal for 10 d	8.2 ± 0.7a	1.9 ± 0.2a	15.4 ± 0.5a	9.0 ± 0.9a	11.5 ± 1.1a
Bloom removal for 20 d	5.2±0.7b	2.1±0.1a	16.0 ± 0.5a	10.0 ± 0.5a	8.0 ± 0.7b
Pod removal after 10 d	4.8±0.5b	2.1±0.1a	16.3 ± 0.4a	8.8 ± 1.1a	6.9 ± 1.1b
Pod removal after 20 d	1.7±0.4c	1.8±0.2a	13.6 ± 0.7b	8.6 ± 0.5a	2.4 ± 0.6c
P value for ANOVA test	0.0001	0.3327	0.0036	0.4991	0.0001

Table 6. Effect of bloom and pod removal on yield of cowpea. Charleston, SC. **Test 2.**

Treatments	# pods/plant	Wt (g)/pod	100 seed wt (g)	# seed/pod	Yield/plant (g)
Control	10.8 ± 0.8a	1.9 ± 0.1b	15.9 ±0.3cd	8.4 ± 0.2a	15.1 ± 0.9a
20% of blooms removed	9.8 ± 0.9ab	1.9 ± 0.1b	16.9 ± 0.2ab	8.7 ± 0.5a	13.4 ± 0.6ab
50% of blooms removed	9.8 ± 0.8ab	1.9 ± 0.1b	16.7 ± 0.2bc	8.5 ± 0.2a	13.7 ± 0.7ab
80% of blooms removed	8.3 ± 0.5bc	1.9 ± 0.1b	16.3 ± 0.3bcd	8.6 ± 0.4a	12.1 ± 0.6ab
10% of pods removed	7.6 ± 0.6bc	2.0 ± 0.1b	16.7 ± 0.1bc	9.1 ± 0.6a	11.4 ± 1.2bc
50% of pods removed	7.7 ± 0.6bc	2.0 ± 0.1b	17.7 ± 0.1a	9.2 ± 0.3a	13.2 ± 1.9ab
80% of pods removed	6.1 ± 0.8c	2.6 ± 0.3a	15.6 ± 0.6d	9.7 ± 0.1a	8.4 ± 1.4c
P value for ANOVA test	0.0024	0.0130	0.0009	0.2234	0.0226

Research Activity: Efficacy of neem extracts for controlling the pests of cowpea at different growth stages.

The study evaluated on farmers fields the efficacy of neem for controlling the pests of cowpea at its different growth stages and their effect on growth performance and yield. The experiment was laid in a randomized complete block design with four replications. Locations were blocks and farmers replications. There were 16 treatments obtained by combining 4 cowpea growth stages and single round of neem treatment at these stages as follows:
1-0-0-0 = spray at vegetative stage only to control pests at this stage.
0-1-0-0 = spray at flower bud stage only to control pests at this stage.
0-0-1-0 = spray at flowering stage only to control pests at this stage.
0-0-0-1 = spray at podding stage only to control pests at this stage.
1-1-0-0 = spray at vegetative and flower bud stages only for pests there.

1-0-1-0 = spray at vegetative and flowering stages only for pests there.
1-0-0-1 = spray at vegetative and podding stages only for pests there.
0-1-1-0 = spray at flower bud and flowering stages only for pests there.
0-0-1-1 = spray at flowering and podding stages only for pests there.
0-1-0-1 = spray at flower bud and podding stages only for pests there.
1-1-1-0 = spray at vegetative, flower bud and flowering stages only for their pests.
1-1-0-1 = spray at vegetative, flower bud and podding stages only for their pests.
1-0-1-1 = spray at vegetative, flowering and podding stages only for their pests.
0-1-1-1 = spray at flower bud, flowering and podding stages only for their pests.
1-1-1-1 = spray at all 4 growth stages-full protection (CONTROL I).
0-0-0-0 = No protection at all (CONTROL II).

The results indicated that the mean highest yield across locations of 832.7 kg/ha was obtained with three applications of neem at 0-1-1-1 (i.e., preflower, flowering and podding). The next two highest yields were 447.3 kg/ha and 438.0 kg/ha obtained with two applications at 0-0-1-1 (flowering and podding) and 1-0-1-0 (vegetative and flowering) respectively. The trend of the results indicated that thrips and pod sucking bugs continue as the main key pests of cowpea and that the effectiveness of neem is obtained with application at all stages of cowpea growth.
I.A.5.b.(2)(j) Current status of research: This work began about 6 years ago. The most sensitive stage to damage by different groups of insects has been defined. The information resulted from applications of insecticides applied at different phenological stages of development of the cowpea crop, thereby protecting the crop at selected growth stages. However, identification of precise “thresholds” by insects is very dynamic and extremely challenging. Often there are complexes of insect pests that occur simultaneously. Also, given that botanical insecticides, such as neem, provide little immediate control but act more slowly as an anti-feedant and growth regulator, the notion of a threshold density of pests may not be applicable. Instead, the approach may be one of preventive treatments, especially in areas where there is a history of infestation of a particular pest. The next phases of research should focus on this. It is anticipated that within the next 5 years, adequate information about the appropriateness of this approach will be determined by tests carried out in farmers’ fields.
I.A.5.b.(2)(k) Documented impact. It is economically prohibitive for most small scale, resource-limited cowpea farmers in Ghana to purchase insecticides. The larger, commercial growers, however, should benefit from knowing that the most sensitive stage of cowpea development is with heavy populations of thrips on the racemes and early blooms. Early pod-fill stage is very sensitive to pod-sucking bugs. Unless viruses are vectored by low numbers of aphids, these often are kept under control by natural enemies. Foliage-feeding pests are rarely a problem in Ghana. Incorporation of available information about insect species (both pest and beneficial) in relation to plant phenology into IPM programs with TOT/FFS will have a major positive impact on cowpea yields in West Africa. If known information about insect pest impact in relation to plant phenology were put into place by farmers, selected applications of neem or other chemicals could increase cowpea yields by 15-20%.

I.A.5.b.(3) Activity #3: Test pilot IPM strategies
I.A.5.b.(3)(a) Priority: Essential
I.A.5.b.(3)(b) U.S. researcher: Shepard
I.A.5.b.(3)(c) HC researchers: Salifu, Owusu-Akyaw
I.A.5.b.(3)(d) Methodology: The methods use for this will rely on previous ones worked out in other parts of the developing world where TOT/FFS are used.

Researchers/Extensionists/NGOs/Farmers participate in activities in the field that help them understand the "process" of IPM. Emphasis is away from "packages" of technology. This activity is where all IPM tactics are brought together in farmers' fields and are carried out as FFS exercises.

I.A.5.b.(3)(e) Anticipated results of activity: More sustainable cowpea production with less reliance on chemical insecticides.

I.A.5.b.(3)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
Greater farm profitability, stability and reduced environmental and health problems	8-10 years	Location-specific IPM programs developed. 50% of cowpea farmers trained in IPM to make informed decisions in their fields.

I.A.5.b.(3)(g) Budget:

IRAD	$ 7,500
CRI	5,000
SARI	10,000
Clemson	8,878
Total (Direct costs only)	$31,378

I.A.5.b.(3)(h) Major changes: Because some farmers feel that extraction of neem from leaves and fruit of neem trees is too laborious, commercial formulations were tested at the TOT/FFS and cowpea action research site (CARS) in the Techiman District of the Brong Ahafo region of Ghana.

I.A.5.b.(3)(i) Progress during past year: Research Activity: Field testing IPM strategies with farmer participants -- Ghana (M. Owusu-Akyaw and J.V.K. Afun).

Methods: Non-formal education methods are being used to train farmers and Agricultural Extension Officers in Farmer Field Schools (FFS) and Training of Trainers (TOT). The last training program was carried at the Cowpea Action Research Site (CARS) at Techiman in the Techiman District of the Brong Ahafo region in Ghana in June 2001. Training for the second (minor) season school resumed in October 2001. Comparisons were made between the recommended insecticides, Karate (lambda cyhalothrin) and Perfekthion (dimethoate), and, commercial neem extract (Neemazal). Farmers' usual practice, which was essentially calendar applications of insecticides, was included in the treatments. Treatments applied by calendar basis were compared with those using field scouting to determine the need for treatment. Sixty farmers (45 males and 15 females) and 17 Extension Officers attended the school during the first season.

Results: Farmers' observations

Grain yield: Even though neem extract produced greater yield than the unprotected crop, farmers were not happy about its performance and therefore, did not consider it a viable alternative to synthetic insecticides, which out-yielded other treatments. However, further work is needed on the efficacy of commercial and farmer-prepared formulations and rates.

Natural enemies: Populations of natural enemies, particularly spiders, were quite low at Techiman compared to Ejura but the farmers observed that all forms of synthetic insecticides killed spiders. Spider populations were higher in neem-treated plots compared to those treated with synthetic insecticides.

Insecticide application: The farmers were most enthusiastic about reducing the number of insecticide applications from their practice of six and above to three based on field monitoring during the season.

Low yields: The one season of the Farmer Field School (FFS) at Techiman has brought home clearly many reasons why farmers' fields are low yielding. Some of the reasons are:

- Poor germination. Most farmers relied on their own old seed stock and do not carry out germination tests prior to sowing.
- Very low plant density due to haphazard planting instead of in rows.
- Lack of knowledge about pest incidence. Farmers often wait to see flowers before initiating insect control.
- Using the wrong chemicals (such as ULV formulations in knapsack sprayers).

Research Activity: Participatory IPM technology testing and adoption (A.B. Salifu et al., SARI). The test of IPM strategies in 2001 was carried out in the Yendi district. A total of 178 participants were involved: 27 extension workers drawn from the Ministry of Food and Agriculture (MoFA), two non-governmental organizations–ActionAid and Management Aid–and 151 farmers. A total of 23 females participated. Major issues that were brought to the forefront in the technology testing and transfer techniques program included the following:

- Better understanding of cowpea crop growth and development, with emphasis on crop and pests management practices for increased production.
- Developing techniques/skills in environmentally sound and sustainable cowpea production, non-formal education and farm record keeping.
- Determining the economics of growing cowpea and to regard cowpea production (including seed preservation and marketing) as a commercial venture and identifying ways to obtain highest return on inputs.

Prior to the commencement of field activities, a curriculum development workshop was organized in Yendi. All stakeholders involved were invited to the workshop. The workshop was intended to:

- Identify issues that will be incorporated into the curriculum for training of trainers (TOT) in IPM technology transfer and farmer field schools (FFS) designed to involve farmers in the technology testing and transfer process for cowpea IPM.
- Produce workplans for season long TOT/FFS.
- Prepare materials needed for field implementation of TOT/FFS.
- Identify special topics and resource persons for TOT/FFS.

Crop Management Trials: AT commencement, TOT participants were divided into five working groups. Each group conducted a crop management trial designed to include:

- Farmer practice plots
- IPM practice plots

Each of the five trial units measured 279m^2 subdivided into two sub plots (15m x 9m) of farmer practice plots and IPM practice plots each with 15 rows of cowpea planted at 0.6m row spacing. Protocol for IPM practice plots included an integration of agronomic practices and plant protection measures. The most appropriate practices/measures to choose from in designing the protocol included:

- Agronomic practices: Specify method of land preparation, water management, soil nutrient management, variety and seed selection, planting spacing/density, weed management, etc.
- Plant protection measures: Specify type of pesticides/pyrethroid/botanicals used and their dosage. Specify the crop growth stage/DAP at application.
- Additional cultural practices that may be peculiar to the farm environment.

FFSs were established and run by the trainee trainers in actual farmers' fields. FFSs provided the opportunity for trainee participants to learn how to conduct IPM technology transfer and use the facilitation and other skills acquired in the TOT sessions. Farmers benefitted from the skills impacted by trainee trainers and also from the direct involvement in IPM and related technology testing. The focus of these FFSs was largely based on processes and less on content. This is because FFS content is very location specific and a particular location may not satisfy possible district differences. The number of FFSs is often proportional to the number of groups borne in the TOT but can be scaled depending on logistics and other resources. In the particular case of the 2001 Program for the Yendi District, there were 5 FFSs of 30 farmers (one had 31). Each FFS consisted of two training plots and a demonstration as follows:

- Farmer practice (1 plot)
- IPM practice (1 plot), and
- Demonstration of non-chemical storage methods (CRSP-developed technology)

FFS trials and protocol of the IPM practice plots were designed after the baseline study (by participants) of cowpea production systems in the location of the TOT.

Participatory Action Research Trials (PART): PARTs were intended to provide the opportunity for participants to validate proven research and indigenous knowledge/technologies, and to provide some technical input into trainee FFSs. Even though PARTs in the TOT were specific to their location, the results were expected to be adapted for subsequent FFSs that participants were expected to establish in their respective zones/districts. PARTs included:

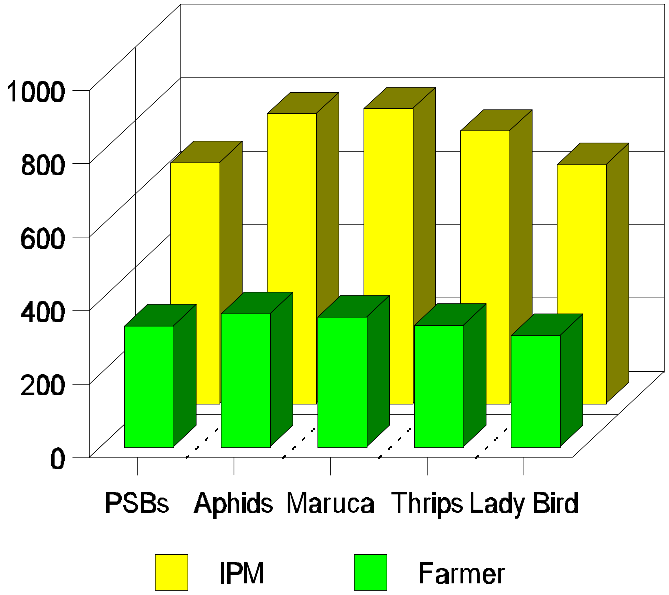
- Soil management and nutrient trials with the following treatments: NPK (10:0:0), animal manure (4 ton/ha), NPK (7.5:7.5:7.5) and NPK (0:10:0). These were compared with no soil amendment.
- Spacing trials using 50 x 20, 60 x 20, 40 x 40 (farmer practice) and 40 x 20.
- Cowpea varietal trials using Clemson 15, Clemson 16, Clemson 21, CAL 11, CAL 18, CAL 19, CAL 20, CAL 21, CAL 24, *Bengpla* (recommended and local check), IT x P, *Valenga*, *Moussa* and *Asontem*. This trial was as a participatory varietal selection (PVS) activity in which farmers and breeders did joint evaluations at specified intervals and crop development.
- Botanicals/bio-pesticide trials. The focus was on neem and *Hyptis*. The trial evaluated the efficacy of *Hyptis* and neem against that of a standard pyrethroid (lambda cyhalothrin) commonly used by farmers.
- Yield loss/pest assessment trials. The objective was to enable participants to find out for themselves the key/important pests at the different cowpea growth stages and their effect on cowpea growth performance and yield. The summary of treatments shown in the Table below produced 16 treatments out of the combination of 4 growth stages and insecticide application at those stages.

GROWTH STAGE	SPRAY CODE	DOMINANT INSECT PESTS
Vegetative	1-0-0-0	Aphids, Leafhoppers, Foliage beetle
Flower bud	0-1-0-0	Flower thrips
Flowering	0-0-1-0	Flower thrips, *Maruca* pod borer
Podding	0-0-0-1	Pod sucking bugs (PSBs), *Maruca*

- Host plant resistance trials: The trial sought to demonstrate the benefit of plant resistance to insects. Varieties used included *Sanzi zie* (collected locally and which farmers indicated appeared to produce "reasonably" with insect attack), Tvx 3236, *Sanzi sanbili* (most resistant identified earlier in the CRSP SARI research), Tvu 1509 and *Bengpla* (susceptible check).

Results of TOT/FFSs: Results of grain yields obtained by IPM versus farmer practices for both TOT and FFS are shown in figures 1 and 2. During the baseline survey, it was revealed that the average practice for producing cowpeas in the Yendi district involved zero sprays using local trailing varieties with two weedings around 3 and 6 weeks after planting respectively. It was therefore not entirely surprising that in both TOT and FFS, aveage yields of cowpea for all groups under farmer practice was about half that of yields obtained under the various IPM techniques deployed. In these kinds of studies however, the biological yield of the crop is often not the core parameter of interest, but instead the grasping of skills and techniques for approaching cowpea protection and production using integration of whole farm techniques. As in the previous years, participants closed the season with abundant confidence. The element of self-mastery of individual and collective skills and techniques added zest to the whole experience of group work.

Even more important in this activity were two additional activities–cowpea utilization and HIV aids awareness–were added to the range field and related activities. The Women in Agricultural Development (WIAD) division of the MoFA ran the cowpea utilization workshop while the Yendi District Health Management Team (DHMT) of the Ministry of Health handled the HIV Aids awareness workshop. Both activities attracted more than 178 participants and received wide acknowledgment by the farmers and particularly the district political authority. The District Chief Executive (the political head) and the Minister for Interior visited the test site (TOT) on separate occasions (see insert of the visit by the DCE as captured by the Daily Graphic of October 24, 2001). The demonstration of CRSP non-chemical storage methods–solar de-infestation, double/triple bagging, especially solarization, were embraced as very effective and potentially cheap in monetary and environmental terms.



SARI holds field school for farmers

THE Savanna Agricutural Research Institute (SARI), in conjunction with the Extension Division of the Ministry of Agriculture, has held a farmers' field school on integrated pest management in Yendi District.

According to Mr Osman Gyasi, an economist at SARI, the exercise, aimed at training trainers, has benefited about 150 farmers, who will embark on farmer-to-farmer transfer of technology.

The District Chief Executive for the area, Mr Mohammed Habib Tijani, who inspected the demonstration farm, commended SARI officials for the technology, which will help a number of farmers to control pest on their farms.

•Dr Asare of SAFARI (front centre) explaining a point about a cowpea demonstration farm to Mr Tijani (third from right) during the inspection. Picture by DAN ADANE.

Figure 1: Grain yield (kg/ha) of cowpea for different Farmer Field School (FFS) groups using farmer crop protection and recommended IPM practices.

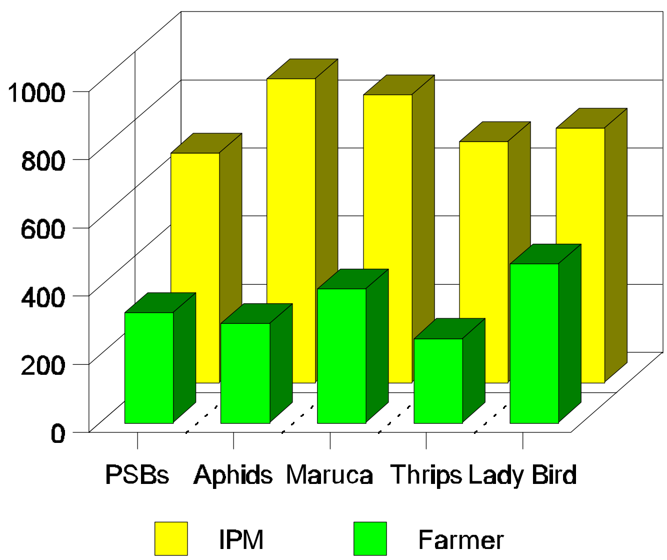


Figure 2: Grain yield (kg/ha) of cowpea for different Training of Trainers (TOT) groups using typical farmer crop protection practice and recommended IPM technology.* * *

Research Activity: Field Testing Pilot IPM Strategies in Cameroon (Georges Ntoukam)

Results and Discussion: In Cameroon, Georges Ntoukam organized a Farmer's Field School. The school was based on a protocol originally developed by A.B. Salifu and Merle Shepard of the Ghana/Clemson project, and disseminated by PRONAF. The school opened on August 5, 2001, the initial activity being the planting of cowpea plots, which were subsequently followed through the entire growing season to harvest. Ten extension people representing several NGO's (CDG, SAILD, a women's group headed by Madame Jackau) as well as PNVRA (Cameroon Ministry of Agriculture) participated. There were 5 women and 5 men. Each of these individuals spent 3 days each week in Maroua, coming in from their several villages for instruction. Each Thursday, they listened to lectures and saw demonstrations from a team of teachers that included an entomologist, an agronomist, an agricultural economist, a plant pathologist, and others. On Friday and Saturday of each week they planted or tended their cowpea plots in Maroua. The test plots were of two types, the traditional farmer's plot, or an improved plot which used the latest technology for cowpea cultivation. Available low-tech technologies such as neem spray's were included. At the end of the growing season, the participants were trained to use CRSP-developed post-harvest storage technologies for the harvested cowpeas.

Each trainee returned to her/his village for the remainder of each week. There the trainee in turn trained 5 farmers in the methods that she/he had just learned. Each of these farmers in turn were asked to demonstrate the new methods to other farmers.

I.A.5.b.(3)(j) Current status of research Ghana: These activities began about seven years ago when Salifu observed a FAO sponsored FFS on rice in Ghana. The approach is based on the model of Training of Trainers (TOT) and Farmer Field Schools (FFS). It also involves a "hands on" approach with researchers working with extensionists and farmers in a participatory way. Excellent progress has been made in cowpea in Ghana and the approach has now been expanded to Cameroon. TOT/FFS should be expanded into all major cowpea production areas of West Africa. This should take place in another 8-10 years.

Cameroon: This was the first year of this work in Cameroon; it was initiated to take advantage of the experience and progress made in the Clemson/Ghana project. The current course will terminate on November 23, 2001 with a demonstration and graduation ceremony attended by administrators of the participating NGO's as well as government officials.

There are reports that FAO will carry out a FFS in northern Cameroon in 2002, focusing on cowpea and CRSP-developed technologies and cultivars. If this happens, Ntoukam is likely to be involved in a substantial way. Thanks to the experience of this initial foray into FFS, he will be better able to contribute to the anticipated FAO initiative.

I.A.5.b(3)(k) Documented impact Ghana: Farmers who participated in the farmer field schools report that their knowledge of cowpea production and crop protection was greatly improved. The TOT/FFS curriculum includes land preparation, plant spacing, seed germination, recognition and conservation of natural enemies as well as pests. In areas where farmers are empowered with this knowledge, yields are higher and production is more sustainable with fewer risks that are associated with commercial chemical insecticides. Other IPM tactics such as resistant plants, improved cultivation techniques and conservation of natural enemies and weed control are important parts of the "best mix" of tactics tailored to specific locations. FFS also provide an entry point for female farmers to gain knowledge about cowpea IPM and production. With the adoption of IPM, farmers can expect at least a 30% yield increase.

Cameroon: Ntoukam plans to evaluate the results of the School and present his report in due course.

I.A.5.b.(4) Activity #4: Identify cowpea germplasm with resistance to insect pests and diseases
I.A.5.b.(4)(a) Priority: (1) Essential
I.A.5.b.(4)(b) U.S. researchers: Fery
I.A.5.b.(4)(c) HC researchers: Ntoukam
I.A.5.b.(4)(d) Methodology: Field trials with cultivars will be tested in Charleston for insect resistance, adaptability and yields. This work will be carried out in South Carolina. In Cameroon, local land races will be evaluated for insect resistance in non-sprayed plots.
I.A.5.b.(4)(e) Anticipated (1 year) results of activity: Pest resistant/tolerant germplasm available.
I.A.5.b.(4)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Identification of insect resistant germplasm that is available for small-scale cowpea farmers in South Carolina and West Africa	8 years	Adoption by significant population of limited resource farmers in South Carolina and West Africa as indicated by surveys

I.A.5.b.(4)(g) Budget:

IRAD	$ 3,000
Clemson	4,000
Total (Direct costs only)	$ 7,000

I.A.5.b.(4)(g) Major changes: Germplasm evaluation also took place in Ghana-CRI.
I.A.5.b.(4)g) Progress during past year: Research Activity: USA--Susceptibility of Pinkeye, Blackeye and green cotyledon cowpea varieties to damage by sucking bug pests (M. Abudulai, M. Shepard, and R. L. Fery).

Methods: Field studies were conducted to screen Pinkeye, Blackeye, cream types and green cotyledon cowpea varieties for resistance to the pod-sucking bugs *Nezara viridula* (L.) and *Leptoglossus phylopus* (L.) in Charleston, SC. The varieties were planted on 12 June 2001. Plots were 3 rows by 4.9 m long with one guard row between plots. The guard rows were planted with Coronet cowpea variety. The experiment was laid out in a randomized complete block design with four replications per treatment. Plots were weeded as needed and no insecticides were applied.

Mature pods were harvested from all three rows. Data were taken on pod and seed damage, number of seeds per pod, 100 seed weight and yield. The data were analyzed using MSTAT-C statistical package and the means were separated at $P < 0.05$ level of significance.

Results: Insect damage between normal cotyledon color and green cotyledon color was about the same. Damage was due to the sucking bug complex, *Nezara viridula* and *Leptoglossus* spp. However, for the pinkeye-type cultivars, the green cotyledon ‘Charleston Greepack’ had less damage than did the ‘Pinkeye Purple Hull BVR’ and the ‘Petite-N-Green’. Within the cream-type cultivars, ‘Tender Cream’ had the same amount of damage as ‘Bettergreen’ (Tender Cream and Bettergreem are near-isogenic lines that differ at the green cotyledon locus). Tender Cream had less damage than ‘DoubleGreen Delight’ and ‘Charleston

Nemagreen'. Considering the blackeye types, 'Green Dixie Blackeye' had more insect damage than 'Bettergrow Blackeye'.

Table 6. Response of Pinkeye, Blackeye, cream type and green cotyledon cowpea to damage by sucking bugs compared to green cotyledon types. Charleston, SC.

Cultivar Class	Cotyledon	100 seed weight (g)	Yield (g)	Percent Damaged
Pinkeye types				
Pinkeye Purple Hull- BVR	Crea			
Petite-N-Green	Green	12.0 D	160.3	42.6 A
Charleston Greenpack	Green	14.0 C	300.4	31.7 B
Blackeye types				
Green Dixie Blackeye		15.3 A	242.0	27.6 BC
Bettergro Blackeye		13.8 C	388.1 B	19.5 E
Cream Types				
DoubleGreen Delight	Green	10.3 F	365.0 BC	25.7 CD
Better Green	Green	11.2 E	492.8 A	21.0 DE
Tender Cream	Crea	11.0 E	325.8 BC	19.2 E
Green Pixie	Green	9.9 G	395.7 B	24.7 CDE
Charleston Nemagreen	Green	11.0 E	398.4 B	25.4 CD

100 seed weight, LSD value (á = 0.05) = 0.3156; Yield, LSD value (á = 0.05) = 76.38; Percent Damage LSD value (á = 0.05) = 5.781

Research Activity – Ghana: Screening cowpea germplasm for resistance to insect pests (J.V.K. Afun and M. Owusu-Akyaw, CRI, Kumasi, Ghana).

Methods: Lines that showed reasonable levels of resistance to the four main groups of insect pests, aphids (15 lines), thrips (4 lines), *Maruca* (5 lines) and pod sucking bugs (8 lines) during the 2000 screening were selected and planted in separate advanced trials in Kwadaso, Ghana. All accessions were each planted in 4-row plots replicated 3 times. All plants in the two middle rows per accession were observed visually for aphid colony size and percent stand infestation at the seedling stage, and for flower thrips damage at raceme stage. Twenty flowers were picked per plot, while all green pods on four plants in the outer rows were removed for *Maruca* damage assessment. At pod ripening stage, 50 pods were picked from the 2 outer rows for pod bug damage assessment. The 2 middle rows were harvested at maturity for grain yield determination.

Results: *Aphis craccivora* infestation was too low during the season to warrant any reasonable assessment of varietal resistance. One of the 4 lines screened for thrips resistance (Accession No. 3710) was identified as the most resistant, while Accession Nos. 4546 and 5040 were the two most resistant lines against *Maruca* in terms of both flower and pod damage. Accession No. 2317 was also selected for pod bug resistance as it had the smallest populations of pod bugs and suffered the least seed damage.

Research Activity: Screening cowpea accessions for yield, pest resistance, and earliness in Cameroon (Georges Ntoukam).

Methods: Work begun three years ago has continued. In conjunction with the price and quality studies carried out by Jess Lowenberg-DeBoer, 160 cowpea accessions were originally obtained from various markets in northern Cameroon. All of these accessions were planted out in duplicate test plots, half of which were sprayed with insecticide and half left unsprayed. Each accession was evaluated each year for plant type, field insect resistance, bruchid, virus and striga resistance.
Results: This year, the 10 most promising materials have been selected and subjected to an additional year of testing. Some of these selected local cultivars have substantial promise, one or more of which have the trait of earliness. This year, work was initiated to purify the best lines through selection of the best, uniform types. This cowpea germplasm collection will be available to Boukar Ousmane when he returns to Cameroon to begin his cowpea breeding program after his Ph.D. program is completed.
I.A.5.b.(4)(j) Current status of research: In the Southeastern U.S., development of green cotyledon genotypes have provided the cowpea industry with new markets. Southern Frozen Foods is planting these new varieties on several hundred acres and consumer demand is high. Several new genotypes have been identified as a result of a vigorous cowpea screening effort at CRI. Working with IITA, Sanzi Sabinli and Ex-Adidome have been identified as parents for resistance to thrips and aphids, respectively. Screening/Breeding activities at SARI continue to identify new materials that are better adapted to conditions in the northern part of Ghana. More emphasis should be placed on insects such at thrips and aphids. Development of cowpea germplasm will continue be a major part of the research and IPM programs. It is estimated that within the next 10 years, major break-throughs in cowpea breeding will occur. This effort will be most successful if it occurs in a participatory way with farmers and extensionists to ensure that the varieties being developed are acceptable by the stake holders.
I.A.5.b.(4)(k) Documented impact: It is clear from work by scientists in the U.S.A. as well as those in W. Africa, that the recently developed cowpea varieties far out-yield the older traditional ones. Excellent progress has been made in pest resistance, especially to cowpea diseases. Breeding efforts have been less successful for sucking bugs and Maruca pod borers. However, with the use of botanical materials such as neem, the high yielding varieties can be protected from these pests. The combination of modern varieties and neem (or other botanical materials) has excellent potential. This has been shown in experimental plots as well as in farmers' fields. Well-adapted, pest resistant, high-yielding varieties will for the core of a sustainable IPM program in cowpea. Combined with other IPM tactics, improved cowpea germplasm has the potential for increasing yields at a sustainable level by over 40%.

I.A.6. Research area: Collect baseline data for impact assessment

I.A.6.a. Background: Baseline and adoption data collected for Senegal and Cameroon. For northern Ghana baseline collected and is being analyzed. For southern Ghana the farming systems review and extension agent survey will be completed by September 1999. Social, environmental, health and nutritional baseline data needed.

I.A.6.b. Proposed research area workplan and subsequent annual progress report:

I.A.6.b.(1) Activity #1: Baseline measures of family units on social, environmental, human health and nutritional impacts of IPM adoption in rural Ghana

I.A.6.b.(1)(a) Priority: (1) Essential, reduce sample size if necessary
I.A.6.b.(1)(b) U.S. researchers: Vander Mey
I.A.6.b.(1)(c) HC researchers: Haleegoah, Abatania, UGL food science researcher to be identified.
I.A.6.b.(1)(d) Methodology: Representative sample of rural family systems will be interviewed before IPM adoption, and at regular intervals (based on availability of funds) for growing seasons after IPM adoption. Questionnaire will inventory farming/IPM practices (environmental health of farms); chemical storage, use and handling; storage practices (environmental and human health issues); bodily protection when handling, using and storing chemicals; changes in knowledge regarding cowpea production, especially cowpea production using IPM techniques; cowpea consumption patterns both as table food and as a weaning food; and standard health measures of children, such as height-to-weight, arm circumference, and age-to-height. "Social" factors include changes in knowledge, increased consumption of cowpeas, and safer use of pesticides. Levels of IPM adoption and reasons for variation, also will be inventoried. Fifty percent of the estimated 200 units to be surveyed will be used as a control for measuring IPM implementation impacts. Funds being requested for 1999-2000 are for initial interviews. These interviews will create the base for longitudinal, panel analyses of the impact of IPM on rural farm families in Ghana.
I.A.6.b.(1)(e) Anticipated (1 year) results of activity: Information on current IPM practices, pesticide handling, storage practices and cowpea consumption.
I.A.6.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Reduce pesticide use and improve environment and health through helping to identify where Farmer Field Schools and more information on nutritional benefits of cowpea needed		

I.A.6.b.(1)(g) Budget:

CRI	$2,500
SARI	3,000
Clemson	500
Total (Direct costs only)	$6,000

I.A.6.b.(1) (h) Major changes: No real changes here. Counterparts at CRI have seen these baselines as extra and costly, so data collection as originally proposed has not been carried out.
I.A.6.b.(1)(i) Progress during past year: The focus group with farmers in the Northern Region was conducted.

A survey of 70 farmers in the Ashanti Region of Ghana revealed that farmers see themselves as really challenged by the pest insect problems on cowpea, and by increasing costs of inputs and decreasing farm profits. Respondents indicated that aphids, flower thrips, and pod borers were very important pests in need of control. While most farmers wash as a way to protect their bodies after handling or using chemicals, most do not use gloves and some do not use any bodily protection at all.

Of the 70 farmers, 63% were male, and 59% were household heads. Respondents' ages ranged from 22 to 85, with a mean of 41.6. On average, this sample of farmers used 1.7 acres for white cowpea and 1.2 acres for red cowpea. Most farmers grew other crops in addition to cowpea, most notably maize (mean = 4.08 acres) and yam (mean = 1.03 acres).

Most farmers relied on neighbors as sources of information related to farming production and marketing information. Other common sources of information included radio (65.2%), discussions with extension staff (63.8%), merchants (43.5%), and field demonstrations (39.1%). Most farmers rarely rely on the chief for information, or upon newspapers and extension publications.

For farmers who store cowpea, most (95.5%) said that they had used sacks as method of storing during the previous year.

A focus group interview was used to gather baseline information at Gbanbaya, a village in the Northern Region of Ghana, in September, 2001. There were 25 men and 5 women farmers. For the main part, farmers grow cowpea for home consumption. Very little cowpea is sold in the markets. Most also will use cowpea as a weaning food. Cowpea is mixed with sorghum and/or maize and fed to weaning children. Cowpea grain and leaves are used for human consumption. Shells and residue are used for animal fodder. The farmers estimated that women do about 70% of all work that is involved in cowpea production. The women plant and harvest and the men weed.

Most farmers get their seed from venders in the market. Cowpea storage is a challenge for the farmers. Many store in shea butter or ash, but still lose their grain and seed to insects. These farmers specifically asked for information on more effective storage. They were assured that as learners and researchers in the field school, they would be testing an alternative to their current storage practices.
I.A.6.b.(1)(j) Current status of research: Stopped until further funding is available.
I.A.6.b.(1)(k) Documented impact: Does not apply.

I.B. Constraint #2: Limited Storage Options

I.B.1. Research area: Adapt CRSP storage technologies to more users

I.B.1.a. Background: Cowpea merchants have somewhat different storage needs than producers. They often handle larger volumes of cowpea and must be able to handle and transport the packages. They currently use storage insecticides. Ash storage would require too much labor and the quantities of ash would be enormous. Solar heating would require substantial labor. Triple bagging seems to be the CRSP storage technology best adapted to their need, but they need bags that can be repeatedly handled and transported.

I.B.1.b. Proposed research area workplan and subsequent annual progress report:

I.B.1.b.(1) Activity #1: Determine a method of cowpea storage suitable for traders: a modified triple bagging may be useful.
I.B.1.b.(1)(a) Priority: (2) High priority
I.B.1.b.(1)(b) U.S. researchers: Murdock
I.B.1.b.(1)(c) HC researchers: Ntoukam
I.B.1.b.(1)(d) Methodology: Woven transparent bags will be obtained from Yaounde/Douala. The treatments will be: (a) a simple woven trans-parent bag (WTB); (b) WTB + a clear bag (CPB); (c) WTB + 2 CPB; (d) WTB + 3CPB. 50 kg of cowpea will be stored in each treatment.
I.B.1.b.(1)(e) Anticipated (1 year) results of activity: Modified triple bagging technique adapted to commercial use in Cameroon.

I.B.1.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Lower storage costs and reduced use of storage insecticides, which contributes to lower consumer prices, greater commercial profits and reduced environmental and health effects		Modified triple bagging used by cowpea merchants in Cameroon

I.B.1.b.(1)(g) Budget:

IRAD $3,000
Total (Direct costs only) $3,000

I.B.1.b.(1)(h) Major changes: None – the work was carried out as planned.

I.B.1.b.(1)(i) Progress during the past year: Objective was to determine if the triple bagging technique could be adapted for the needs of traders, who commonly handle cowpea grain in 100 kg bags. The bags they use need to be very strong, since they are often handled fairly roughly. The seams of clear plastic bags are relatively weak, and may burst if triple bagged cowpeas are handled in the usual manner by traders and their workers. A potential solution to this problem was noted several years ago: woven plastic bags, which are very strong, yet allow a degree of inspection of the enclosed grain. These are available in Maroua and other cities in the region. To test the viability of this system, the experiments involved storing 50 kg lots of VYA cowpea that had been artificially infested with cowpea weevils in woven plastic bags alone, and in woven plastic bags surrounding 50 kg of cowpea held in a single plastic bag, double plastic bags, or triple plastic bags. We needed to know whether we could get by with one clear plastic bag, or two, or if three were essential. Traders are very cost conscious, and we anticipate they will cut down the number of clear plastic bags to the minimum necessary to preserve their cowpeas.

The 50 kg cowpea grain lots stored in woven plastic bags alone and those stored in a woven plastic bag surrounding a single clear plastic bag were heavily infested during the 4 month storage period. Treatments with double and triple plastic bags were well preserved.

I.B.1.b.(1)(j) Current status of research: During the final storage season of the current five year extension, we are initiating experiments with a cowpea trader in Maroua who will test the double and triple bagging system and provide us with feedback on the pros and cons of this approach.

I.B.1.b.(1)(k) Documented impact: None as yet.

I.B.2 Research area: Technology development for steam treatment of cowpea before storage

I.B.2.a. Background: Insect infestation is recognized as a major limiting factor in cowpea production and utilization. The hydrothermal treatment of cowpeas has been proposed as an alternative treatment for food grade cowpeas. Field testing in commercial warehouses, rural community farms and markets are underway in FY 00. Preliminary results show high interest from farmers and market intermediaries as the method prevents re-infestation of the treated cowpeas. Triple bagging has been used and proven effective in Cameroon. The two technologies will be introduced to cowpea producers and market operators in southern Ghana. Steaming cowpea seeds at atmospheric pressure followed by low-temperature drying, especially solar drying, has been shown to prevent subsequent infestation by *Callosobruchus* *maculatus*. For most treatments, this process has also resulted in lower water absorption, reduced protein solubility, and increased hardness of cooked seeds. However, some combinations of steaming and drying conditions actually reduced cooked seed hardness. Steaming/drying also increased decortication efficiency of treated seeds. It is necessary to elucidate the mechanism by which this technology protects cowpeas against insect attack – whether it is due to seed hardening, which may compromise the ultimate food value of the seeds – or by some other mechanism, e.g. related to ultraviolet radiation, which may allow both protection and conservation of food value.

I.B.2.b. Proposed research area workplan and subsequent annual progress report:

I.B.2.b.(1) Activity #1: Determine a method of cowpea storage suitable for different operators and evaluate socioeconomic impact.
I.B.2.b.(1)(a) Priority: (2) High
I.B.2.b.(1)(b) U.S. researchers: Nyankori
I.B.2.b.(1)(c) HC researchers: Sefa-Dedeh, Afoakwa, Sakyi-Dawson
I.B.2.b.(1)(d) Methodology: The technologies of hydrothermal treatment and triple bagging will be introduced to cowpea farmer groups, warehouses and market operators. The performance of these technologies and acceptability by the different groups will be determined.

Specific Methodology: Cowpea (*Vigna unguiculata*) was obtained from cowpea farmers in a village in Ga Rural. The samples were bagged in jute sacks and kept under cold room conditions (4°C) until used. A 3x3x4 factorial experimental design with sample treatment (hydrothermal treatment, solar drying and untreated seeds), packaging material (jute sack, plastic drum, polypropylene sack) and storage time (0, 2, 4 and 6 months) was performed. All samples were packaged in the three different packaging materials and sent to a local market and stored for 6 months. The storage warehouse of women cowpea traders were used. Samples were analyzed immediately after processing and after every two months in storage for the following indices; moisture content, 1000 seed weight, water absorption capacity, cooked seed texture and soaked seed texture. The AACC (1983) method 44 -15A of drying at 130ºC for one hour in a forced air oven was used for the moisture content determination. The weight of a hundred whole seeds was determined and the corresponding 1000-seed weight calculated. Seed water absorption was measured using the method of Sefa-Dedeh *et. al.* (1978). Cooked seed texture was determined by cooking the cowpea seeds in boiling water for 0, 30, 60, 90 and 120 minutes and the texture of the cooked seeds analyzed using a TA. XT2 Texture Analyzer (Stable Micro Systems, Surrey, England). The test cell used was the Warner-Bratzler Blade. The cooked seeds were placed longitudinally across the groove in the sample holder and cut perpendicularly across the axis of the seeds. The peak force required to cut through 5 seeds was determined. The test conditions used were; test speed of 1.5 m/s, distance of 11mm. The test was replicated five (5) times and the average peak force recorded. The hardness of seeds soaked for 1, 3, 6, 18 and 24 hours was determined using a TA. XT2 Texture Analyzer (Stable Micro Systems, Surrey, England). The test was replicated five (5) times and the average peak force recorded. The data collected were analyzed statistically using analysis of variance for all the indices measured and statistical significance was at $p \leq 0.05$.
I.B.2.b.(1)(e) Anticipated (1 year) results of activity: Cowpea storage options available to the farming and market operators.
I.B.2.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and

indicator:

IMPACT	TIME FRAME	INDICATOR
Reduced losses of cowpea due to insect infestation	5 years	Wide-spread adoption of CRSP storage technologies

I.B.2.b.(1)(g) Budget:

UGL	$10,000
Clemson	3,750
Total (Direct costs only)	$13,750

I.B.2.b.(1)(h) Major changes: None

I.B.2.b.(1)(i) Progress during the past year Moisture Content: The moisture content of the various samples varied at the time of storage as a result of the different treatments. The hydrothermal and the solar dried samples had lower moisture levels than the untreated.

Table 1. Changes in moisture content of cowpea seeds during storage (%).

Sample Treatment	Packaging Material	Storage time (Months)			
		0	**2**	**4**	**6**
Hydrothermal Treatment	Jute Sack	9.07	10.06	10.12	11.67
	Plastic Drum	9.07	9.96	10.37	11.91
	Polypropylene sack	9.07	10.01	11.25	11.58
Solar Drying	Jute Sack	11.82	12.81	13.06	13.09
	Plastic Drum	11.82	13.32	13.25	13.68
	Polypropylene sack	11.82	12.43	12.98	13.01
Untreated (Control)	Jute sack	12.22	13.09	12.96	13.48
	Plastic Drum	12.22	13.37	13.63	13.85
	Polypropylene sack	12.22	12.79	13.02	13.35

This suggests that the drying method applied to cowpea seeds before storage influences the initial moisture contents of the seeds. Trends observed for the cowpea seeds during storage varied according to the sample treatment given to the seeds prior to storage. Storage caused increases in moisture content of the seeds from all the treatment during the six months period. Moisture increases of 9.07-11.67%, 9.07-11.91% and 9.07-11.58% were respectively recorded for the hydrothermally treated samples packaged in the jute sacks, plastic drums and polypropylene sacks during the six months storage. Similar increasing trends of 11.82-13.68% and 12.22-13.85% were observed for the solar-dried and the control samples packaged in plastic drums respectively during storage. The samples packaged in the plastic drums showed comparatively higher increases than those of the jute and polypropylene sacks. Likewise, the untreated samples showed relatively higher trends of moisture increases during storage as compared to the steam treated and solar-dried samples. However, the increases in moisture content observed for all the stored samples were not high enough to affect the quality of the seeds during the six months of storage. Analysis of variance showed that there was no significant effect ($p \leq 0.05$)on the moisture content of the seeds during the storage period with the treatment and packaging materials used.

Thousand seed weight: The thousand seed weight is a measure of the density of the cowpea seeds. During storage of the cowpea seeds increasing levels of 153.81-156.90 g, 153.81-160.12 g and 153.81-158.96 g were respectively recorded for the samples stored in the jute sack, plastic drum and polypropylene sacks. The solar-dried and the control samples also showed consistent increases in the 1000 seed weight with storage time. The untreated (control) samples however showed comparatively higher trends in weight which might be due to their ability to absorb moisture faster than the other samples during storage. Similar increasing trends were observed on cowpea samples stored at the Mampehia Cowpea farm and retail markets in Accra (CRSP Annual Report, 2000). Statistical analysis conducted on the data indicated that storage time and sample treatment significantly affected ($p \leq 0.05$) the 1000 seed weight of the samples. Packaging material had no effect on the 1000 seed weight.

Water Absorption Capacity: The rate of water absorption was highest after one hour of soaking the samples exhibiting differentials in the water absorption after this period. Comparable water absorption was measured for all samples after 24 hours of soaking though the untreated seeds generally absorbed more water. This means that, the different treatments affect the rate of water absorption as well as the amount of water absorbed after a period of soaking. The difference in behavior of the steamed seeds may be due to changes that occur in the seed coat of this particular variety of cowpea (Pamproba) during steaming. Analysis of variance revealed that the effect of steaming and soaking time on the water absorption capacity was significant ($p \leq 0.05$). There was however no significant effect ($p \leq 0.05$) on the water absorption capacity by the different packaging materials used.

Soaked Seed Texture: The soaked seed texture decreased with increasing soaking time. This means that, the peak force required to cut through the seeds decreased as the time of soaking increased. This was observed in all the samples, irrespective of the packaging material, treatment or storage time. Rapid decreases occurred in the seed hardness of both the steamed and unsteamed seeds as well as the solar dried seeds after 6 hours of soaking. ANOVA conducted on the soaked seed texture showed that the treatment given to the seeds had a significant effect ($p \leq 0.05$) on the soaked seeds texture. This means that the different treatments resulted in significantly different textural characteristics. The period of soaking also had a significant effect on the texture of the seeds. The effect of storage time on the soaked seed texture was significant indicating that some degree of hardness was developed in the seeds during the storage period. The different packaging materials however had no significant effect on the soaked seed hardness of the seeds.

Cooked Seed Texture: Texture is an important attribute of food which affects its acceptability by consumers. Generally, the cooked seed texture decreased with cooking time. On the contrary, the cooked seed texture increased with storage time. However, the rate of increase was relatively higher in the steamed seeds, which could be due to the steam treatment. The solar-dried seeds gave intermediate results between the steamed and untreated seeds. The effect of storage on the cooked seed texture of all the samples was significant, even though, there was not much difference at the end of the storage period. At the end of the storage period, the texture of the cooked seeds were harder than those of the initial storage period. This means that, storage also plays a role in the hard-to-cook defect which develops in cowpea seeds during storage. Analysis of variance showed that the cooking time and the treatment given to the seeds had a significant effect on their rate of cooking, however, the different packaging materials used had no significant effect on the rate of cooking of the seeds.

Conclusion: The quality characteristics of cowpeas are important for their optimum utilization. These characteristics must therefore be preserved as much as possible during storage in order to attain or improve national food security. The different packaging materials used as well as the processing methods given to the cowpeas prior to storage led to only slight variations in the quality of the cowpea seeds with all the measured indices during storage. The packaging materials did not have any significant effect on the quality of the seeds during the period of the study. Likewise, there were no weevil infestation in all the cowpea seeds stored using the various packaging materials within the six months of storage. This means that all the packaging materials as well as the treatment processes employed could be used to effectively store cowpeas for long periods of time without storage problems.

I.B.2.b.(1)(j) Current status: This research has addressed the use of steaming (hydrothermal treatment) both for protecting treated seeds against subsequent infestation by insects and for its effect on seed characteristics related to cookability and other utilization parameters. Because the present TC has insisted that no further effort be expended on seed storage aspect of the work, it will no longer be pursued using B/C CRSP funding.

I.B.2.b.(1)(k) Documented impact: These cowpea storage methods are suitable for different cowpea operators and have been made available to some farmers and market operators to help reduce storage losses of cowpeas due to weevil infestation.

I.B.2.b.(2) Activity #2: Determine the mechanisms and effects of steaming cowpeas

I.B.2.b.(2)(a) Priority: (2) Essential

I.B.2.b.(2)(b) U.S. researchers: Chinnan

I.B.2.b.(2)(c) HC researchers: Sefa-Dedeh

I.B.2.b.(2)(d) Methodology: Based on studies of heat and mass (water) transfer during steaming and solar and non-solar drying vs. seed cooking times, hardness at specific cooking times, and insect resistance; optimal conditions for the application of this technology will be sought. Treatments will be applied to a range of West African varieties. Chemical and physical analysis of treated seeds will be applied to elucidating the mechanism of the effect.

Specific Methodology: Steaming treatment of cowpea seeds appears to result in undesirable changes in the textural characteristics. This has been suggested to be due to starch gelatinization in the outer layers of the seed. Studies on flour samples have shown that the degree of starch gelatinization is dependent on the initial moisture content of the sample. The objective of the study was therefore to investigate the effect of varying seed moisture content on the degree of gelatinization and its possible influence on cooked seed texture. The work is being conducted as a part of the doctoral dissertation by a student from Ghana, N. S. Komey. Initial experiments were conducted to determine the most suitable method for increasing the initial moisture content of the cowpeas. Three methods were investigated:

- adding a known amount of water and equilibrating to the desired moisture content;
- soaking the seeds for a specified amount of time; and increasing the moisture content above the desired value followed by drying at 55°C to the desired moisture content.

Cowpea (*Vigna unguiculata*) was obtained from the Ministry of Food and Agriculture Extension Farms at Mampehia village in Ga Rural. A 2x2x4x4 factorial experimental design with steaming method (laboratory steam jacket and traditional aluminum steamer), drying process (solar and oven drying), steaming time (0, 5,10, 15 mins.) and storage time (0, 2, 4, 6 months) was performed. Steamed cowpea were divided into two and one part solar-dried (40-50°C) for 48 h to attain moisture content of about 10%; the other part was oven-dried

(50°C) for 24 hours. The treated samples were packaged into polypropylene bags and stored under ambient temperature conditions (28°C) for a period of six (6) months.

Samples were analyzed immediately after processing and after every two months in storage for the following indices; moisture content, 1000 seed weight, water absorption capacity, degree of insect infestation, cooked seed texture and soaked seed texture. Degree of weevil infestation was determined by selecting two hundred seeds at random from the storage container. The number of seeds with holes were then separated from those without holes, counted and calculated as the percentage of the total number of seeds selected. Cooked seed texture was determined by cooking the cowpea seeds in boiling water for 0, 30, 60, 90 and 120 minutes and the texture of the cooked seeds analyzed using a TA. XT2 Texture analyzer (Stable Micro Systems, Surrey, England). The hardness of seeds soaked for 1, 3, 6, 18 and 24 hours were also determined using a TA. XT2 Texture analyzer (Stable Micro Systems, Surrey, England). The test was replicated five (5) times and the average peak force recorded. The data collected were analyzed statistically using analysis of variance for all the indices measured and statistical significance was at $p \leq 0.05$.

Samples (100g) of each treatment from the experiment above (1) were placed in 500ml bottles and inoculated with ten pairs of day-old adults of the weevil *Callosobruchus maculatus* and covered with muslin cloth. all treatments were set up in triplicate. Two weeks after inoculation, all dead adults were removed and the eggs laid estimated by sampling 46 seeds three times from each replicate. The samples were observed for adult emergence.
A similar experiment was done with different cowpea varieties, to test the influence of seed coat pigmentation on the effectiveness of the hydrothermal treatment to protect against insect attack.
I.B.2.b.(2)(e) Anticipated (1 year) results of activity: A firmer grasp on the underlying causes of the steaming effect on insect resistance and confirmation of the ability of this process to also improve seed cookability simultaneous with imparting insect resistance.
I.B.2.b.(2)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Increased cowpea availability due to improved storage	3-5 years	Adoption of this technology for grain storage

I.B.2.b.(2)(g) Budget:

UGL	$4,000
UGA	4,825
Total (Direct costs only)	$8,825

I.B.2.b.(2)(h) Major changes: See (j) – Current Status
I.B.2.b.(2)(i) Progress during past year: From the results of the steaming study, the most suitable method of hydration, in terms of reproducibility, was found to be a combination of soaking and drying. The soaking time required to attain a moisture content slightly greater than the required was determined from a regression equation relating soaking time to moisture content. The seeds are soaked for the specified time and then dried at 55°C till the desired moisture content is attained. Protocol has been established to appropriately provide the steaming treatment, discretely remove layers of cotyledon material, and analyze the samples of layers for changes in starch properties using enzyme assays.

Moisture Content: The moisture content of the cowpeas treated using the two steaming methods varied slightly at the onset of storage with values ranging between 6.96-7.64% and 7.23-8.17% for the solar-dried and oven-dried samples respectively. Storage caused increases in moisture contents of all the seeds during the six months period. Analysis of variance on the data showed that there was significant differences ($p \leq 0.05$)in the moisture content of the seeds with storage time. The steaming and drying methods however did not have any effect on the moisture.

Degree of weevil infestation: The level of weevil infestation of cowpea seeds is a measure of quality expressed in the seeds. The presence of increasing numbers of infested seeds in a particular bag of cowpeas therefore is regarded as inferior quality seeds. The results showed that the degree of weevil infestation with the treated seeds during storage did not change with storage. The untreated samples however increased in weevil infestation (up to 5%) during the six months of storage. This means that the different steaming methods used (laboratory steam jacket and traditional aluminum steamer)used to treat the cowpea seed before storage protected the seeds from weevil infestation.

Water Absorption Capacity: The water absorption capacities of all the samples processed using the two steaming methods were similar. The rate of water absorption for the samples treated using the steam jacket was slightly higher than that of the aluminum steamer and the control after one hour of soaking. After 24 hours of soaking, however, the amount of water absorbed by the different samples were comparable, though the untreated seeds generally absorbed more water. Differences in the rate of water absorption was not wide for the different steam treatments used. Analysis of variance revealed that the effect of steaming time and soaking time on the water absorption capacity was significant ($p \leq 0.05$). There was however no significant effect ($p \leq 0.05$) on the water absorption capacity by the different steaming methods used.

Soaked Seed Texture: The soaked seed texture decreased with increasing soaking time in all the samples, irrespective of the steam treatment, drying method or storage time. The peak force required to cut through the seeds steamed using the steam jacket was slightly higher than those of the aluminum steamer and the untreated seeds. ANOVA conducted on the texture of the seeds showed that the steaming method had no significant effect ($p \leq 0.05$) on the soaked seeds texture. This means that the two different steam treatments processes resulted in similar textural characteristics. The effect of storage time on the soaked seed texture was significant indicating that some degree of hardness was developed in the seeds during the storage period.

Cooked Seed Texture: Generally, the cooked seed texture of all the samples increased with storage time. The rate of increase was however relatively higher in the untreated seeds. The effect of storage on the cooked seed texture of all the samples was significant, even though, there was not much difference at the end of the storage period. At the end of the storage period, the texture of the cooked seeds were slightly harder than the initial storage period. This means that, storage also plays a role in the hard-to-cook defect that develops in cowpea seeds during storage. Analysis of variance showed that the cooking time and the treatment given to the seeds before storage had a significant effect on their rate of cooking, however, the different drying methods used had no significant effect on the texture of the cooked seeds.

Oviposition and Adult Emergence: Significant high members of eggs were laid on solar dried cowpeas compared to oven dried samples irrespective of the steaming method. Steamed samples dried in the oven were not protected from weevil attack. Steaming and solar drying significantly reduced the number of emerging adults.

Preliminary results indicate that cowpeas with colored seed coats were not protected using the hydrothermal treatment and solar drying. It is suspected that the effectiveness of the hydrothermal treatment is not only a function of heat exchange and solar drying but the inherent chemical composition of the seed coat may contribute. The role of polyphenols in the possible blocking of the reaction(s) which occur during hydrothermal treatments is not ruled out.

Conclusion: The two steaming methods (laboratory steam jacket and traditional aluminum steamer) used to treat the cowpea seed before storage protected the seeds from weevil infestation and led to only slight variations in the quality characteristics of the cowpea seeds with all the measured indices during storage.

The effectiveness of the hydrothermal treatment is a function of multiple physical and chemical changes.

I.B.2.b.(2)(j) Current status: This research has addressed the use of steaming (hydrothermal treatment) both for protecting treated seeds against subsequent infestation by insects and for its effect on seed characteristics related to cookability and other utilization parameters. Because the present TC has insisted that no further effort be expended on seed storage aspect of the work, it will no longer be pursued using B/C CRSP funding. However, it is important to note that steaming is a standard food processing technique and has been widely used to develop quick cooking cereal and legume seeds. The efforts to modify cooking time and research into ancillary effects of cowpea food quality will continue and are the subject of PhD research at UGA.

I.B.2.b.(2)(j) Documented impact: The cowpea steaming methods used have been made available to cowpea farmers in The Ga North District of the Greater Accra Region. The adoption of this new technology would help increase cowpea availability in the area due to the improved storage methods.

I.C. Constraint #3: Insufficient Utilization Research

I.C.1. Research area: Food and nutritional quality testing—U.S. and West African cultivars

I.C.1.a. Background: Developing a database of nutritional and functional quality of cowpea cultivars and breeding lines is essential to enable breeders to select for superior food/nutritional quality. Twelve U.S. and West African cowpea cultivars provided by Drs. Hall and Murdock were extensively analyzed for food and nutritional quality (proximate analysis, amino acid profile, vitamin content, cooking time/texture, akara making) during the last FY. At UGA, 50 cultivars provided by Dr. B. B. Singh, IITA, are currently being analyzed for proximate composition and cooking time. Sweet cultivars and others with promising food quality are being assayed in Ghana in collaboration with Dr. Larry Murdock and Dr. K. O. Marfo.

I.C.1.b. Proposed research area workplan and subsequent annual progress report:

I.C.1.b.(1) Activity #1: Assess chemical and nutritional quality of promising cultivars

I.C.1.b.(1)(a) Priority: (1) Essential
I.C.1.b.(1)(b) U.S. researchers: Phillips, Chinnan, Eitenmiller, Hung, McWatters
I.C.1.b.(1)(c) HC researchers: Sefa-Dedeh, Sakyi-Dawson, Tano-Debrah*.*
I.C.1.b.(1)(d) Methodology: Depending on available funds, seeds supplied by colleagues both within the CRSP and associated with it will be analyzed for proximate, amino acid, and vitamin composition using standard chemical and microbiological protocols. Anti-nutritional components, e.g., tannins will be evaluated. Nutrient availability will be assessed using in vitro methods. Seed cooking times, seed texture, decortication behavior, foaming and akara-making quality will be assessed as previously described.

Specific Methodology: Cooking time on the remaining seeds provided by Dr. B.B. Singh, IITA was estimated using the automated pin-drop cooker developed by the project. Twenty two seeds are loaded into the device which is lowered into boiling water. Timing begins when the water returns to the boiling point. As each seed softens enough to allow penetration by the equal-force probes, the event is recorded electronically. The time required for half of the seeds to cook is reported.

Six new cultivars of cowpea (Pamproba, Face-to-Face, IT87D-195Y, Emosue, Adom and Asetenapa) were used for the study. IT87D-195Y, Adom and Asetenapa were obtained from the Crop Research Institute of the Council for Scientific and Industrial Research (CSIR), Fumesua, Ghana . Emosue, Pamproba and Face-to-Face were obtained from the Ministry of Food and Agriculture Extension Farms at Pokuase. The moisture, crude protein (N x 5.7), fat and ash contents were determined by the AOAC Approved methods 925.10, 920.87, 920.85, 923.03 and 963.09 respectively (AOAC 1990). Carbohydrate contents were determined by difference. The tannin content was determined using the A.O.A.C. (1990) Methods 9.098-9.100. Determination of starch, reducing sugars and total sugars were done following a modified method of Luff-Schoorl's which has been approved by the European Community (Directive 79/786/EEC) for testing starches and sugar solutions (AOAC, 1990). Stachyose, raffinose and other sugars were extracted from the samples and analyzed using High Pressure Liquid Chromatography (HPLC) following the methods of Havel *et al.* (1977) and Aitzemuller (1978).

Seed dimensions (length, width and thickness), seed water absorption and seed swelling capacity were determined by the methods of Sefa-Dedeh *et al.* (1978) and Sefa-Dedeh and Stanley (1979). The foam expansion, foam stability, fat absorption, emulsifying properties and stability of the flours were measured using the methods described by Yasumatsu *et al.* (1972). Dehulling efficiency of the seeds were done following the method described by Komey (1999).

Cooked seed texture and soaked seed texture were analyzed using a TA.XT2 Texture analyzer (Stable Micro Systems, Surrey, England). The test cell used was the Warner-Bratzler Blade. The cooked and soaked seeds were placed longitudinally across the groove in the sample holder and cut perpendicularly across the axis of the seeds. The peak force required to cut through 5 seeds was determined. The test conditions used were; test speed of 1.5 m/s, distance of 11mm. The test was replicated five (5) times and the average peak force recorded. The data collected were analyzed using multifactorial analysis of variance. Differences among means were compared using multiple range test at a level of significance of 0.05.
I.C.1.b.(1)(e) Anticipated (1 year) results of activity: The database relating genetic

background and food and nutritional quality will be expanded by the number of samples analyzed. Cowpea utilization profile (providing various weighted indices) will be developed.

I.C.1.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
Production and consumption	5 to 10 years	Wide-spread adoption of cowpeas with superior quality improved lines

I.C.1.b.(1)(g) Budget:

UGL	$10,000
UGA	5,000
Total (Direct costs only)	$15,000

I.C.1.b.(1) (h) Major changes: None

I.C.1.b.(1) (i) Progress during past year Cooking Times**:** Cook times or the remaining IITA cultivars are shown in Table 1 below. The data were sorted by cook time and the differences among cultivars was quite striking, ranging from about 16 minutes to about 32 minutes. This indicates that genetic background, and perhaps cultural practices may have a major impact on this important parameter.

Table 1:

SAMPLE NAME	COOK TIME** Avg, Min	Std Dev
IT84S-2246-4	15.55	0.99
IT97K-569-9	18.18	4.16
IT93K-734	19.26	3.28
IT93K-637-1	19.51	3.67
IT93K-693-2	19.66	1.72
IT94K-440-3	19.91	1.77
IT93K-513-2	20.15	1.39
IT87D-941-1	20.15	2.18
IT93K-273-2-1	20.21	2.67
IT97K-1042-8	20.62	6.01
IT89KD-391	21.71	1.03
IT89KD-374-57	21.77	1.88
IT95K-222-14	22.06	4.16
IT95K-1479	22.12	1.08
IT96D-610	22.61	3.88
IT90K-76	24.43	1.93
IT86D-719	26.60	0.32
IT95K-1491	26.90	1.44
IT88D-867-11	27.03	3.54
Dan Ila	27.58	1.52
IT93K-452-1	29.48	1.07
IT97K-570-25	30.08	3.28
Kanannado	31.96	0.67
IT96D-660	31.97	1.32
IT82D-889	Insufficient Sample	

Proximate composition: The moisture content of the cowpea varieties studied ranged between 7.89 and 9.99% respectively in IT87D-195Y and Adom. indicating that the cowpea seeds contain less moisture and can be stored for longer period without quality defects.

Table 2: Proximate Composition of Cowpea Seeds

Cultivar	Moisture (%)	Crude Protein (%)*	Fat (%)	Ash (%)	Carbohydrate (%) [1]
Pamproba	8.5	23.96	2.48	4.46	58.26
Face-to-Face	9.8	22.84	3.28	3.28	58.06
IT87D-195Y	7.89	23.92	2.02	4.7	60.18
Asetenapa	9.81	25.11	2.54	3.38	53.41
Adom	9.99	26.55	2.82	3.98	56.09
Emosue	7.86	27.37	3.1	3.72	58.02

Mean values from triplicate analyses (g / 100g, dry matter), [1] Calculated by difference, * N x 5.7

The protein content of the different cultivars were high ranging from 22.84% in Face-to-Face to 26.55% in Adom (Table 2). Similar values have been reported for various cowpeas (Frimpong, 1995; Lambot, 2000; Sefa-Dedeh *et al.,* 2001). This property of cowpea makes it important to the human diet from a nutritional standpoint. The differences in protein content may be due to genetic and environmental factors. The fat, ash and carbohydrate contents of the new cultivars did not show much variation. The different cultivars had fat content between 2.02% and 3.28% while their ash contents also ranged from 3.28 - 4.70% with Face-to-Face and IT87D-195Y having the lowest and highest respectively. Carbohydrate contents in the new cultivars studied also ranged between 53.41% and 60.18% (Table 2).The proximate composition of the six new cowpea cultivars investigated were similar and comparable to what has when reported for other cowpea varieties (Bressani, 1985; Sefa-Dedeh *et al.*, 2000).

Starches and sugars: The starch content measured ranged between 48.56 mg/100g for Emosue to 98.48 mg/100g for Adom. This wide variation was not detected in the reducing and total sugar levels. Mean values observed for the reducing sugars ranged from 10.45-12.19 mg/100g for Face-to-Face and Emosue respectively, whilst those of the total sugars ranged from 38.48-47.11 mg/100g respectively for Adom and Pamproba. The starch content of cowpea is expected to have an influence on the functionality of the variety. It could be observed from this study that the higher the starch content, the lower the reducing and non-reducing sugars and vice versa.

Mono, di and oligosaccharides: Studies on the new cowpea cultivars indicated different levels of sugars (glucose, sucrose, raffinose, stacchyose, xylose, fructose and maltose) in the cowpea seeds. The glucose levels ranged between 0.03 g/100g in Emosue to 1.15 g/100g in Face-to-Face whilst sucrose ranged from 1.01 g/100g in Pamproba to 1.72 g/100g in Emosue. Earlier studies revealed that Sweet cowpeas contain glucose and sucrose levels of 1.15 g/100g and 4.66 g/100g respectively, explaining why the sweet cowpea cultivar is sweet in taste. Very high levels of glucose (1.70 g/100g) and sucrose (5.40 g/100g) were found in some dehulled cowpea samples, suggesting that the process of dehulling increases the glucose and sucrose content of cowpea seeds. Raffinose and stacchyose levels in the cowpeas also ranged from 0.53 g/100g and 2.58 g/100g respectively in Face-to-Face to 0.90 g/100g and 5.00 g/100g respectively in Emosue. This means that Emosue has high levels of oligosaccharides and its consumption will bring about high incidence of flatulence if consumed undehulled. The levels of xylose, fructose and maltose were negligible with values between 0.00- 0.07 g/100g in IT87D-195Y.

Tannins: The results showed did not show much varietal differences in the tannin content of the new cowpea cultivars. Face-to-Face was observed to have the lowest value of 0.54 mg/100g sample whiles IT87D-195Y had the highest value of 0.64 mg/100g sample. Analysis of variance showed no significant differences ($p \leq 0.05$) in the varieties.

Dehulling efficiency: Dehulling is an important means of improving the utilization of cowpeas and other legumes. This is because it results in an improvement of protein digestibility through the reduction of anti-nutritional factors such as tannins found in the seed coat. It also leads to faster cooking times and removes a large proportion of oligosaccharides which causes flatulence especially in children. Dehulling efficiency of the cowpea varieties ranged from 52.64% in Pamproba to 91.80% in IT87D-195Y. The results in this study showed that with the exception of Pamproba which had dehulling efficiency of 52.64%, all the varieties had very high dehulling efficiency values ranging from 63.22% in Asetenapa to 91.80% in IT87D-195Y. This means that with the exception of Pamproba, all the studied varieties have loosely bound hulls attached to their cotyledons making them easier to dehull.

Seed water absorption: Trends in water absorption for all the samples were similar. There were rapid rates of water absorption for the cowpea seeds during the first six hours, after which the rates slowed down as the seeds reached their saturation points . Even though the results showed similar trends for all the varieties, the rates of water absorption were higher in IT87D-195Y and Adom than in the other varieties with Pamproba showing the lowest water absorption capacity during the first six hours of soaking. All the cultivars have similar water absorption capacities and good hydration properties.

Flour water and oil absorption capacities: The importance of water and oil absorption capacity of cowpea protein is reflected in its necessity in ground formulations, meat replacers and extenders, doughnuts, and soups. Adom recorded a lower water absorption capacity (134.64%) and oil absorption capacity (108.14%) as compared to Emosue which had water absorption capacity of 152.03% and oil absorption capacity of 109.24%.

Seed swelling capacity: The most critical period for the swelling of cowpea seeds seem to be the first 6 hours of soaking. Swelling, measured as per cent increase in dimension of seeds was more pronounced in the length and thickness of the seeds as compared to the width. In this study, the cowpeas had similar swelling pattern but slightly different hydration capabilities. The observed trends showed that all the cowpea varieties exhibited similar swelling pattern with respect to the seed length, thickness and width.

Foam expansion and stability: The foaming abilities of cowpea flours is a desirable characteristic for the production of several traditional cowpea-based food products such as 'akara'. It was observed that Emosue had the highest foam expansion followed by Face-to-Face and IT87D-195Y in that order. These results indicate that Emosue, Face-to-Face and IT87D-195Y would be more suitable for products that require high whipping properties such as akara production. The Pamproba may not function well in products requiring foam expansion.

Soaked seed texture: The soaked seed texture decreased with increasing soaking time for all the varieties. There were sharp decreases in the maximum cutting force for all the samples between 1 and 6 hours of soaking. Thereafter, the decreases were gradual up to 18 hours of soaking and then leveled up till 24 hours of soaking. The six cowpea cultivars studied were therefore observed to exhibit similar soaked seed texture.

Cooked seed texture: The cooked seed texture of the cowpea varieties were monitored using a Warner-Blatzler blade in a TA XT2 texture analyzer and the maximum force required to completely cut through the cooked seeds were measured. Generally, there were decreases in the cooked seed texture with cooking time for all the samples. Higher peak force values were recorded for Pamproba at the initial cooking times which tended to level up with the other varieties during cooking leading to softening of the seeds. Little variations in the cooked seed texture were observed for the six cultivars studied, suggesting their relative similar textural behavior during cooking.

Conclusion: The six new cowpea cultivars (Pamproba, Face-to-Face, IT87D-195Y, Emosue, Adom and Asetenapa) contain high amounts of nutrients, with fairly high protein contents. Variation in chemical composition of the six new cultivars of cowpea studied were minimal except for Emosue which has relatively high levels of oligosaccharides (raffinose and stacchyose).

I.C.1.b.(1)(j) Current status:
I.C.1.b(1)(k) Documented impact: The nutritional, functional and textural database of the six new cowpea cultivars has become available for use by interested researchers and policy-makers. The importance of cowpea flours from these varieties as binding agents in food applications such as soups as well as meat rolls and comminuted meats has been elucidated. Thus, cowpea proteins can be used as substitutes to obtain suitable water binding properties for different food formulations.

I.C.2. Research area: Product development

I.C.2.a. Background: Several years of research on formulating, producing, and disseminating weaning foods have resulted in reliable techniques for accomplishing these goals, wide-spread adoption of which would dramatically improve weanling, and young child nutrition. However, some 1.5 billion episodes of diarrhea occur annually world wide in children under the age of five years resulting in over 3 million deaths. Traditional cereal-based weaning foods and water are sources of pathogens such as *Shigella spp.* enteropathogenic *Escherichia coli, Campylobacter jejuni,* and *Salmonella*, all capable of causing diarrhea. The ability of fermented maize-based weaning foods to inhibit these pathogens has been associated with low pH due lactic and acetic acids. Exposure of bacteria to a moderately acidic environment can result in cells that survive longer when subsequently placed in a more acidic environment and cross-protection against other environmental stresses such as heat and osmotic stress. The ability of *Shigella* to adapt to acidic environments such as fermented maize-based weaning foods in Ghana and other West African countries has not been determined. Weanling children are most vulnerable to malnutrition and diarrheal disease but older children and, especially, pregnant and nursing women, would benefit from increased consumption of the high quality protein, folate and other B-vitamins in cowpea. These needs coupled with increasing populations in urban areas suggests profound impact may be realized through development of convenience/street foods based on cowpea, which would also provide income to processors and vendors. While formulating such foods would use the same techniques developed for weaning foods, producing a variety of acceptable flavors and textures is more challenging. In the U.S., consumption of beans and cowpeas continues to be very limited due to the time and effort required to prepare them in traditional ways and the lack of novel products made from them. In addition to steaming treatments to produce fast cooking peas, efforts to better understand the functional behavior of cowpea proteins, starches, and non-starch polysaccharides, and to develop processes for making cowpea ingredients suitable for incorporation into American foods and food processes is required.

I.C.2.b. Proposed research area workplan and subsequent annual progress report:

I.C.2.b.(1) Activity #1: Safety of cowpea-based weaning foods
I.C.2.b.(1)(a) Priority: (1) Essential
I.C.2.b.(1)(b) U.S. researchers: Beuchat
I.C.2.b.(1)(c) HC researchers: Sefa-Dedeh, Sakyi-Dawson, Tano-Debrah
I.C.2.b.(1)(d) Methodology: Several strains of S. flexneri isolated from patients suffering from shigellosis in African countries will be obtained from the Centers for Disease Control and Prevention. Strains will be tested for their ability to adapt to reduced pH in culture media. The procedure will be to culture the pathogen in laboratory broth with defined composition, then subject cells to reduced-pH environment achieved with lactic and acetic acids. Strains with increased acid tolerance will be examined for tolerance to elevated temperatures. A survey of S.

flexneri and other pathogenic organisms in weaning food ingredients will be mounted in Ghana.

Specific Methodology: Research to determine the survival and growth characteristics of unadapted, acid adapted, and acid shocked cells of *Shigella flexneri,* a pathogenic foodborne bacterium, in fermented, maize-based weaning foods, with and without fortification with cowpea flour, will continue. Inoculated weaning foods stored for up to 3 days at different temperatures will be monitored. Results will be valuable in developing recommendations and guidance to vendors of weaning foods, as well as to preparers of weaning foods in the home, concerning microbiological safety. Previous studies revealed that exposure of *Shigella flexneri* to acidic environments resulted in increased tolerance of the pathogen upon subsequent exposure to acidic conditions. Fermented weaning foods that are not consumed immediately after preparation may be held for a few hours, then warmed before feeding to children. A study was done to determine if acid-adapted and acid-shocked cells of *Shigella flexneri* are cross protected against mild heat treatment. *Shigella flexneri* was grown at 37?C for 18 h in tryptic soy broth (TSB) containing no glucose (TSBNG) (unadapted cells) and TSBNG supplemented with 1% glucose (TSBG) (acid-adapted cells). Cells grown in TSBNG for 18 h were heat shocked at 48?C for 15 min (unadapted heat-shock cells). Cells were then inoculated into TSB (contains 0.25% glucose) acidified with acetic, lactic, or propionic acids to pH 4.5, 4.0, or 3.5 and incubated at 37?C for 6 h. Survivors were enumerated by plating acidified suspensions on tryptic soy agar (TSA) after incubating for 0.5, 1.0, 1.5, 2.0, 4.0, and 6.0 h.

Cowpea-based weaning foods were formulated using maize (*Zea mays*) and cowpea (*Vigna unguiculata*) obtained from the Ministry of Agriculture, Accra, Ghana, and packaged in three different packaging materials and stored for microbiological analysis using standard methods. A 2x2x3x5 factorial experimental design with dehydration method (solar-drying and oven-drying), cowpea fortification level (0 and 20%), packaging materials (aluminium foil pouches, polyethylene bags placed in metal cans and transparent plastic containers) and storage time (0, 2, 4, 6 and 8 weeks) was performed. Solar-dried and oven-dried weaning foods were prepared with 0% and 20% cowpea, packaged into the three packaging materials and stored under ambient conditions (28°C) for 8 weeks and analysed immediately after processing and after every two weeks for microbial and chemical quality. The safety of the products were evaluated using standard microbiological analysis. Serial dilutions of 10^{-5} and 10^{-6} were used for the solar-dried products, and 10^{-3} and10^{-4} for the oven-dried products. Enumeration of viable organisms and yeast and moulds were carried out on Plate Count Agar (PCA, Oxoid CM325, Harts., England) and Potato Glucose Agar (PGA, Fluka 70139, Buchs, Switzerland) respectively. PCA plates were incubated for 24 hours at 37?C and the PGA plates at 30ºC for 2 days. Lactic Acid Bacteria were enumerated on deMan, Rogossa and Sharpe (MRS) Agar and incubated for 24 hours at 37?C. MacConkey Agar (Merck 1.05465, Darmstadt, Germany) was used to culture coliforms by incubating the plate at 37ºC for 24 hours. Chemical analyses was conducted on the weaning foods using standard analytical methods. Moisture content of the samples was determined using a Shimadzu Moisture Balance (Model EB-330 MOC) at 330?C. pH and titratable acidity measurement were taken by mixing 10g of sample with 100ml distilled water. The mixture was allowed to stand for 15 minutes and shaken at 5 minutes intervals. The supernatant was filtered and the pH measured using a Lab pH meter (ATC pH Meter, Hanna Instrument, Wood Socket, USA). Ten (10) ml aliquots of the filtrates were titrated against 0.1M NaOH using phenolphthalein indicator. Determinations were done in triplicates and acidity calculated as gLactic Acid/100g sample. The data collected were analysed statistically using analysis of variance for all the indices measured using a significant level of $p \leq 0.05$.

I.C.2.b.(1)(e) Anticipated (1 year) results of activity: These experiments will reveal the availability of *S. flexneri* to undergo changes in tolerance to acidic environments and elevated temperature. Results will enable follow-up studies to be designed with the objective of characterizing the behavior of *S. flexneri* in maize-based Ghanaian weaning foods fortified with cowpea.

I.C.2.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
Weaning foods that are both more nutritious and safer	5 years	Reduce incidence of diarrhea in populations

I.C.2.b.(1)(g) Budget:

UGL	$6,500
UGA	1,500
Total (Direct costs only)	$8,000

I.C.2.b.(1)(h) Major changes:

I.C.2.b.(1)(I) Progress during past year U.S.: Populations of unadapted cells *Shigella flexneri* that were not heat shocked, unadapted heat-shocked cells, and acid-adapted cells inoculated into TSB acidified to pH 3.5 with acetic, lactic, and propionic acids rapidly decreased, while a more gradual decline was observed at pH 4.0. Populations of cells remained nearly constant at pH 4.5, regardless of acidulant used. Significantly (p ? 0.05) higher numbers of acid-adapted cells and unadapted heat-shocked cells, compared to unadapted cells that were not heat shocked, were recovered from TSB acidified (pH 3.5) with acetic or lactic acids. The population of unadapted heat-shocked cells decreased 5 $\log_{10}$ CFU/ml after 30 min in TSB acidified to pH 3.5 with acetic acid. Chloramphenicol (100 ìg/ml) was added to an 18-h TSBNG culture of *S. flexneri* before heat shocking to determine if synthesis of new proteins is responsible for the observed increase in acid resistance. Chloramphenicol prevented the development of acid tolerance in heat-shocked cells, indicating a need for synthesis of heat-shock proteins for acid resistance. Results indicate that exposure of *S. flexneri* cells unadapted to an acidic environment to a mild heat treatment renders them more tolerant to acidic conditions and may enhance their survival and ability to grow in acidic foods such as fermented maize-based weaning foods traditionally fed to weaning children in Ghana and other West African countries.

HC–Moisture: The results of earlier studies indicated that cowpea fortification of the traditional weaning foods increases the protein quality and quantity, enhances the chemical quality and as well increases the water absorption capacity of the products with only slight moisture uptake during storage. In this study, the moisture content of the stored cowpea-based weaning food products increased slightly during the storage period from 4.01-7.11% and 5.05-7.67% respectively for the oven and solar-dried products with all the packaging materials used. Generally, products stored in the aluminum foil pouches had relatively higher moisture increases than the other packages used. Even though slight variations in moisture contents of the products were observed during storage, there was no significant effect ($p \leq 0.05$)on the moisture content with the drying method, packaging material and the cowpea fortification levels. The cowpea-based weaning foods formulated can therefore be stored under ambient temperature for long periods of time without problems with moisture uptake.

pH and Acidity: The pH of the weaning food products varied with the different packaging materials and drying methods used during storage. Generally, the pH of the products were observed to decrease slightly during storage with all the various treatments and packaging materials used. Analysis of variance (ANOVA)conducted on the data indicated that the drying method and fortification level significantly affected ($p \leq 0.05$) the pH, but storage time and packaging material had no significant effect on the pH. The titratable acidity of the products varied with storage time, drying methods, fortification levels and packaging materials used. Generally, slight increases in titratable acidity of the products were observed during storage with all the various treatments and packaging materials used. Statistical analysis conducted on the data indicated that the packaging material and storage time had no significant effect ($p \leq 0.05$) on titratable acidity of the weaning foods. However, the drying method used and fortification level had significant effect on titratable acidity The factor for interval means showed that the oven-dried and fortified products differed significantly from the solar-dried and unfortified products. Even though the variations in the acidity levels were not wide the trends observed confirms the observations in the pH determinations. This explains that the cowpea-based weaning foods formulated can be stored for longer periods with only slight variations in their pH and titratable acidity levels.

Coliforms: All the products in the different packaging materials had no coliform counts throughout the storage period. Coliforms when present in foods indicate processing and/or post-processing contamination. Foods contaminated with coliforms are therefore regarded as unsafe for human consumption, since the consumption of such foods causes food borne infections. The products were thus regarded as safe for human consumption.

Lactic acid bacteria: Storage caused general decreases in the Lactic Acid Bacteria (LAB) populations with the unfortified solar-dried weaning foods. LAB in the products packaged in the aluminum foil pouches, metal cans as well as those in the plastic containers decreased from 6.25 -5.69$\log_{10}$cfu/g, 6.25-5.74 $\log_{10}$cfu/g and 6.25-5.45 $\log_{10}$cfu/g respectively. Likewise, LAN in the cowpea-fortified solar-dried weaning foods products packaged in aluminum foil pouches and metal cans decreased from 5.28-5.15 $\log_{10}$cfu/g and 5.28-4.98 $\log_{10}$cfu/g respectively. However, those packaged in the plastic containers showed slight increase in LAB population from 5.28-5.65 $\log_{10}$cfu/g during the eight weeks storage period. Even though the packaging materials, cowpea level and storage time showed slight differences in LAB population, they had no significant effect (p ?0.05) on the LAB population. The drying method used however significantly affected (p ? 0.05)the LAB population. The observation therefore suggests that the population of LAB in the weaning foods shows no much variation with storage time of the products.

Yeast and molds: The weaning foods that were processed using the oven driers had no yeast and mold counts. Similarly, the unfortified oven-dried products packaged in the plastic containers showed no yeast and mold count throughout the entire storage period. During storage of all the oven-dried products, only few yeast and mold counts were observed in the products with all the different packaging materials. However, the fortified products showed slightly higher numbers than the unfortified products with storage. Interval for factor means reveals that the fortified products had more yeast and mold count than the unfortified. Yeast and mold populations differed slightly for all the products throughout the rest of the storage time. Generally, yeast and mold counts increased from week 0 to 2 but it decreased at weeks 4, 6 and 8 of storage. On the whole, the microbial population of the cowpea-fortified weaning foods were lower than that of the unfortified. The implication is that cowpea-based weaning foods are safer for human consumption even after long storage periods.

Conclusion: The drying method, cowpea fortification level and storage time influenced the microflora and chemical characteristics of the traditional cowpea-fortified weaning food products. The cowpea-fortified weaning blends formulated and the oven-dried products were of better microbial quality than the unfortified and the solar-dried products. The process of oven drying and cowpea fortification can therefore be effectively used to improve the shelf stability and nutritional quality of traditional weaning foods. The packaging materials (aluminum foil pouches, polyethylene placed in metal cans and transparent plastic containers) used for the studies can all be effectively used to store the weaning foods with only minimal change in quality during prolong storage periods.

I.C.2.b.(1)(j) Current status of research: Populations of unadapted cells *Shigella flexneri* that were not heat shocked, unadapted heat-shocked cells, and acid-adapted cells inoculated into TSB acidified to pH 3.5 with acetic, lactic, and propionic acids rapidly decreased, while a more gradual decline was observed at pH 4.0. Populations of cells remained nearly constant at pH 4.5, regardless of acidulant used. Significantly (p ? 0.05) higher numbers of acid-adapted cells and unadapted heat-shocked cells, compared to unadapted cells that were not heat shocked, were recovered from TSB acidified (pH 3.5) with acetic or lactic acids. The population of unadapted heat-shocked cells decreased 5 $\log_{10}$ CFU/ml after 30 min in TSB acidified to pH 3.5 with acetic acid. Chloramphenicol (100 ìg/ml) was added to an 18-h TSBNG culture of *S. flexneri* before heat shocking to determine if synthesis of new proteins is responsible for the observed increase in acid resistance. Chloramphenicol prevented the development of acid tolerance in heat-shocked cells, indicating a need for synthesis of heat-shock proteins for acid resistance. Results indicate that exposure of *S. flexneri* cells unadapted to an acidic environment to a mild heat treatment renders them more tolerant to acidic conditions and may enhance their survival and ability to grow in acidic foods such as fermented maize-based weaning foods traditionally fed to weaning children in Ghana and other west African countries.

I.C.2.b.(1)(k) Documented impact: Information characterizing the ability of *Shigella flexneri*, a major cause of gastroenteritis in weaning children and adults in Ghana and other countries in west and east Africa, to survive and grow in fermented maize-based weaning food will be obtained. Weaning foods that have a lower risk of causing shigellosis and death of weaning children. Nutritious and safer cowpea-based weaning foods that have long shelf lives have been developed using traditional processing methods. This will help reduce the problem of protein energy malnutrition as well as the high incidence of diarrhea in the populations of Ghana.

I.C.2.b.(2) Activity #2: Develop cowpea-based convenience foods for children and adults for production and marketing in urban areas in the region and in the U.S.

I.C.2.b.(2)(a) Priority: (1) Essential

I.C.2.b.(2)(b) U.S. researchers: Phillips, McWatters, Chinnan, Hung

I.C.2.b.(2)(c) HC researchers: Sefa-Dedeh, Sakyi-Dawson, Tano-Debrah

I.C.2.b.(2)(d) Methodology: Continuing research conducted both in the U.S. and the HC on composite flour applications, computer optimization will be used to formulate nutritious foods for school-aged children and for adults from mixtures of cowpea and oilseeds (peanut, soy), cereal grain (rice, wheat, maize, sorghum, millet), roots/tubers (cassava, yam) and sources of vitamins and minerals such as cowpea leaves, sprouted cowpeas, and palm oil. Cowpea flour will be made with and without decortication (unpigmented varieties). Processed cowpea materials including those derived from hydrothermal-treated cowpeas and composite blends will be processed by extrusion, baking, roasting, and steaming. They will be assessed for rheological properties, gelling, water binding, fat binding, and for applications in baking using standard methods and instruments. Building on very original findings relating the functionality of cowpea flours and pastes to milling technique, particle size, and disruption of cell wall materials, the potential of wet milling vs. dry milling will be further investigated. Sensory tests will be conducted in the U.S., Ghana and Senegal among target consumer groups. Micro- and small-scale operators in the Ghana Food Cluster Group will be involved in the market and process evaluation for possible adoption

Specific Methodology: White fonio (*Digitaria exilis)*,a relative of crabgrass is an important cereal in certain areas of Burkina Faso and Mali. Although it is very small-seeded and difficult to decorticate, processes to do so exist, and fonio is a popular food where it is produced. Blending cereals and legumes is widely practices to improve nutritional quality. However, utilization of blends (composite flours) in baking yeast-raised breads is challenging since non-cereal proteins interfere with the gluten networks necessary for good bread production. Soft-wheat products such as cookies and biscuits are somewhat more forgiving since gluten is less important. The possibility of making sugar cookies from fonio and cowpea-containing flours was investigated using the following formulations shown in Table 1.

Prototype snack/street foods designed to be acceptable to adults and older children were developed using extrusion cooking. An MPV Baker Model MPF 1700-30 twin screw extruder was used to process the dough. The screw configuration (Designated # 6) was modified from one recommended by the manufacturer and featured sufficient mixing and shearing zones to plasticize a food dough containing a significant level of legume flour (Table 2). Experiments were conducted using a blend of decorticated cowpea flour (California blackeye) and rice flour (50% each, dry basis). Feed rate was 8-10 kg/hr dry basis with a moisture content of 22%. A screw speed of 400 rpm and a slit die with dimensions of 2mm by 25mm were used. Products were dried to <3% water and flavored with meat flavors for informal consumer testing. Nutrient composition was calculated using Food Processor® Software.

Cowpea-fortified plantain 'fufu' flour and 'Tatale' mix flour were processed using traditional methods. Plantain, maize and cowpea were obtained from a local market in Accra, Ghana and used for the study. The flours (Plantain 'fufu' flour and 'Tatale' mix flour) were prepared and fortified with cowpea flour at concentrations of 10% and 20%. The 'Tatale' mix flour was also prepared and fortified with cowpea at concentrations of 10% and 20%. Cowpea flour (100%) was also used for the preparation of 'tatale' mix. This was done in an attempt to increase the protein content of the products and to evaluate the effect of cowpea fortification on the various quality indices of the products. The cowpeas were dehulled and oven dried at 60°C for 24 hours and milled into flour. Unripe plantain 'fufu' flour was prepared by washing, peeling and cutting the unripe plantain into cubes. This was blanched for 5 minutes, oven-dried at 50°C for 24 hours and milled onto flour. Some of the products were fortified with cowpea flour at 10% and 20% levels. For the 'tatale' mix flour, overripe plantain was wash, peeled and blended into a thin paste. A mixture of blended ginger, onion, pepper and salt was added and mixed together. Wheat flour was added as binding agent at 20% concentration. Cowpea flour was then added to a portion at 10% and 20% concentrations, and thoroughly mixed to produce a thin paste. Again 100% cowpea flour was used together with the ingredients to produce the paste. The various tatale mix pastes were drum-dried into flakes and milled into flour. Changes in chemical, physico-chemical and functional properties were investigated. The Association of Official Analytical Chemist Approved Methods 14.004, 14.063, 7.045, 14.006 and 7.050 (AOAC, 1990) were used for the determination of moisture, crude protein, crude fat, ash and crude fibre respectively. The water absorption of the plantain flours was determined by modification of the method reported by Beuchat (1977). The rheological properties of the flour samples were determined using the Brabender Viscoamylograph. Sensory evaluation was performed to determine the acceptability of the product using the 7-point hedonic scale method. Thirty (30) untrained panellists were used to determine the effect of cowpea fortification on the acceptability of the products. The sensory quality characteristics include colour, taste, flavour, texture (softness) and overall acceptability. The texture (softness) of the fried 'tatale' was determined using the TA.XT2 texture analyzer. The peak force required to cut through a piece of 'tatale' was determined. The test conditions were; test speed – 2mm/s; and distance 10mm. The test was replicated five times and the average peak force recorded.

Evaluation of the quality characteristics of products derived from cowpea-based nixtamalized corn were conducted to determine their functional and sensory qualities during and after processing. A 2x2x3 factorial experiment with cowpea fortification (0 and 15%), alkaline treatment (nixtamalized and non-nixtamalized) and fermentation time (0, 24 and 48 hours) was designed to formulate the products. Maize and cowpea were obtained from a local market in Accra, Ghana and food grade calcium hydroxide $Ca(OH)_2$ from Spectrum Laboratory Chemicals in New Jersey, USA and used for the study. The chemical, physico-chemical and functional properties of the cowpea-based nixtamalized flours and snacks were investigated. The AOAC(1990) Method 14.004 and AACC (1983) Method 02-03 were used for the determination of moisture and fat acidity respectively. The water absorption of the flours was determined by modification of the method reported by Beuchat (1977). Thirty (30) untrained panelists were asked to indicate their degree of acceptability of the products by scoring on a 15 cm linear scale. The sensory quality attributes scored were colour, taste, texture (crispiness) and overall acceptability. The texture (hardness) of the products were determined using the TA.XT2 Texture Analyzer connected with a cylinder probe adaptor (150 mm). The peak force required to cut through a piece of snack product was determined. The test was replicated five times and the average peak force recorded.

I.C.2.b.(2)(e) Anticipated (1 year) results of activity: Cowpea-based ingredients and convenience foods will be available for processors and consumers. Their nutritional profiles and physicochemical properties will be available to assist consumer food choices and processors in finding applications.

I.C.2.b.(2)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
Improved nutrition and health among target people	5 years	Wide-spread availability of cowpea-based ingredients

I.C.2.b.(2)(g) Budget:

UGL	$10,000
UGA	15,399
Total (Direct costs only)	$25,399

I.C.2.b(h) Major changes: None

I.C.2.b(i) Progress during past year: All eight sugar cookie formulations had good dough handling properties and would not require the use of dough conditioners or alterations in the manufacturing process to accommodate their use. The 100% wheat cookie had the greatest spread ratio (5.86) and the 75% wheat/25% cowpea, the least (4.39). The 50% fonio/50% cowpea cookies required the most force (720 N) to shear and the 50% wheat/50% fonio the least (399 N). The 100% wheat and the 50% wheat/50% cowpea cookies had the lightest color and the 25% wheat/75% fonio, the darkest. Appearance, color, and texture were not affected by component flours. Cookies containing 100% wheat or 50% wheat/50% fonnio received the highest hedonic ratings for flavor (7.1 and 6.7, respectively) and overall acceptability (6.9 and 6.5, respectively). All other formulations were unacceptable. These results confirm the difficulty in incorporating (unprocessed) legume flours into baked products because of deterioration of both flavor and texture.

Table 1. Mean sensory ratings for consumer acceptance of sugar cookies containing varying levels of wheat, fonio, and cowpea flours[1].

Flour[2]	Appearance	Color	Flavor	Texture	Overall
100% W	6.8	6.8	7.1 a	6.9	6.9 a
50% W, 50% F	6.3	6.3	6.7 ab	6.7	6.5 a
50% W, 50% C	6.8	7.0	4.8 d	6.4	5.2 b
33% W, 33% F, 33% C	6.5	6.2	4.8 d	5.8	5.0 b
25% W, 75% F	6.1	5.9	5.9 bc	5.7	5.5 b
25% W, 50% F, 25% C	6.2	6.1	5.5 cd	6.0	5.2 b
75% F, 25% C	6.2	5.9	5.5 cd	5.9	5.4 b
50% F, 50% C	6.4	6.3	4.9 cd	5.9	4.9 b
Pr > F[3]	0.5678	0.1441	0.0001	0.0756	0.0001

[1]A 9-point hedonic scale with 1 = dislike extremely and 9 = like extremely was used. Means in each column not followed by the same letter are significantly different as determined by Fishers least significant difference (LSD) at <0.05.[2]W = wheat, F = fonio, C = cowpea.
[3]Probability > F.

The extruded products were ribbon shaped with large cells and fairly thick cell walls and resembled pork skins (rinds) – (*Chicharron* in Spanish), which are very popular among a number of ethnic groups in the US, especially among both European and African Americans from the South as well as Hispanics. The texture was relatively hard. However, informal consumer testing indicated promising acceptability. These products were packaged and presented as part of an event promoting the CRSPs in Washington. They were given the working name "CriSPs" for this promotional effort. Nutrient analysis (Table) showed the snacks to have less than half the fat of real pork rinds, and much better protein quality (protein score of 100 vs 20). They were also a good source of dietary fiber and of folate,

Table 2 Nutritional Data for a 100 g (3.53 oz) serving of Cowpea/Rice CRiSP compared to the needs of the 11-14 year old child (female)

Nutrient	Amount	% RDI	Nutrient	Amount	% RDI	Nutrient	Amount g/100g	Protein Score %
Calories	431.25	19.68	Folate	350 mcg	234	Histidine	0.4107	149
Protein	14.649 g	31.66	Calcium	205.36 mg	17.11	Isoleucine	0.5654	138
Carbohydrate	71.311 g	23.1	Copper	0.5305 mg	21.39	Leucine	1.0781	111
Dietary Fiber	7.8207 g	35.94	Iron	12.279 mg	82.14	Lysine	0.8471	**100**
Total Fat	10.61 g	14.55	Magnesium	124.88 mg	44.49	Met + Cys	0.3936	109
Vitamin A	376.83 IU	9.412	Manganese	1.8397 mg	52.2	Phe + Tyr	1.30	141
Thiamin- B1	0.5134 mg	47.06	Phosphorous	261.4 mg	21.39	Threonine	0.522	104
Riboflavin-B2	0.1455 mg	11.12	Potassium	636.61 mg	21.39	Tryptophan	0.1711	106
Niacin-B3	2.5841 mg	17.97	Selenium	11.782 mcg	26.53	Valine	0.6931	135
Vitamin B6	0.3765 mg	0.265	Zinc	2.4215 mg	20.54			
Vitamin E	1.3519 mg	17.11						

providing ten times as much as pork rinds. These products have been presented to the management of Sylvia's Restaurant who have expressed interest in the possibility of licensing and marketing them.

Cowpea fortification caused considerable improvement of the nutritional quality of the plantain products. The moisture content of the products showed no major variations with cowpea fortification. Only slight variations ranging from 9.45% to 8.27% in the unfortified and 20% cowpea fortified plantain flours. However, the use of 20% cowpea as a fortifying agent effectively increased the protein (3.29-6.27%), ash (2.03-2.78%), fat (1.42-2.22%) and fibre (0.74-0.97%) contents of the plantain products. Similar increases in the proximate analysis were observed for the 'tatale' mix flours with cowpea fortification. This makes cowpea fortification viable options of increasing the nutrient profile of plantain products. Statistical analysis conducted on the data indicated that the cowpea fortification level significantly affected ($p \leq 0.05$) the proximate composition of the products. Multiple range analysis showed that the observed variation was between the 0% and 20% cowpea levels.

Generally, decreases in the pH of the plantain products were observed with consequential increases in titratable acidity with the addition of cowpea. The pH of the 'fufu' flour products decreased from 5.22 to 4.93 with 0% to 20% cowpea fortification with a concomitant increase in titratable acidity of the products. This might have resulted from the fermentation of the carbohydrate in the product especially with the cowpea during the preparation of the products.

The addition of cowpea to plantain 'fufu' and the 'tatale' mix flours reduced the water absorption capacity of the products. The swelling capacity of the products showed variations with the addition of cowpea at different levels. The swelling capacity at both 70°C and 28°C decreased with increase in cowpea concentration. However, the swelling capacities of the products were higher at 70°C than at 28°C. This might be due to the partial breakdown and softening of the starch granules, which facilitate the penetration of water. This may account for the observation that, swelling capacity at 70°C is higher than at 28°C. There were also decreases in the softness (increase peak force) of the 'tatale,' with increase in the level of cowpea fortification which is a desired quality by most consumers.

Sensory Characteristics: The color of the products with 0%, 20%, and 100% cowpea concentration were moderately acceptable to the panelists while the product with 10% cowpea concentration was accepted slightly. Differences in the flavour of the products were observed with the addition of cowpea at different concentrations. The flavour of the unfortified product were the most preferred. The flavour of the product with 20% cowpea concentration was liked moderately and those with 10% and 100% cowpea concentrations were liked slightly. Variations in the taste of the products were observed from the sensory analysis. The taste of the unfortified product was most preferred, and those with 10% and 20% cowpea concentrations were moderately liked. The product with the 100% cowpea concentration was however neither liked nor disliked . Major differences were observed in the texture (softness) of all the products with different cowpea concentration. The texture (softness) of the unfortified product was liked extremely, that with 10% cowpea concentration was liked moderately, and that with 20% cowpea concentration was liked slightly. The texture (softness) of the 100% cowpea fortified product was however neither liked nor disliked. The data indicated that the overall acceptability of the unfortified product was high. The products to which cowpea was added at concentrations of 10% and 20% were liked moderately and slightly respectively. The product with 100% cowpea concentration was neither liked nor disliked. Analysis of variance on the data indicated the cowpea fortification had significant effect on the color, flavor taste, texture and overall acceptability of the products. However, the cowpea-fortified products were acceptable and therefore could conveniently be introduced into the market as a new convenient food product with high nutritional value.

Nixtamalized Corn Flours and Snacks: The color, flavor and aroma of the nixtamalized products varied depending upon the sample treatment. The nixtamalized flour products swelled quickly within 1-5 minutes and possesses higher swelling capacities than the non-nixtamalized flours. The unfermented flours in each group had a higher water absorption capacity than the fermented flours. Moisture content of the nixtamalized flours and corn snacks were lower than that of the dough from which they were made. Fat acidity levels and textural properties of the products varied from one product to another. ANOVA showed that the process of nixtamalization and cowpea fortification had significant effect ($p \leq 0.05$) on moisture content, fat acidity and textural properties of the nixtamalized flours as well as the corn snacks. Sample treatment did not have significant effect on the texture (instrumental) of corn snacks. For all the sensory indices there was significant effect of sample variation ($p \leq 0.05$). The mean scores for each sensory index showed that the unfermented nixtamalized corn snacks and the 48 hours fermented nixtamalized corn snacks were the most acceptable among the nixtamalized and cowpea-fortified corn snacks. Variations in product quality characteristics were observed, which were attributed to the different treatments namely, fermentation, nixtamalization (alkaline treatment) and cowpea fortification. The cowpea-fortified nixtamalized corn flours as well as the snacks produced were however acceptable

making cowpea fortification and nixtamalization viable techniques for the production of convenience foods which can be made available to processors and consumers in Ghana.
I.C.2.b(j) Current status of research: The sugar cookie application work has been completed. Composite flour breads made from mixtures of wheat, raw cowpea flour, and pre-gelatinized (extruded) cowpea flours were prepared and evaluated for sensory and physicochemical characteristics. Data are being analyzed and will be reported. Systematic studies to optimize the pork rind/Chicharron product are underway. The goal is to create a wide enough array of textures for consumer testing. Initial flavoring was acceptable but can probably be improved. One goal is to retain the desirable flavor while eliminating sodium glutamate from the flavor mixture. Complete details of the process are being withheld from general publication until a patent disclosure can be completed.
I.C.2.b(k) Documented impact: A formula and processing method for using cowpea flour in a basic sugar cookie recipe were successfully developed; however, future research for this baking application should investigate the use for extruded cowpea flour instead of raw flour if elimination of the beany flavor is desired. Beany flavor is more acceptable to Asian and African cultures than to American consumers who were the primary participants in this study. Extrusion modifies the flavor of cowpea, and may also reduce the interaction of cowpea proteins with wheat gluten, improving baking performance. Preliminary data indicate that extruded blends of cowpea and rice may be marketed as a healthful snack in the U.S. and possibly in West Africa and Latin America. If this is true, dramatic increase in demand for cowpeas could result.

I.C.2.b.(3) Activity #3: Disseminate cowpea food processing technologies to micro-, small- and medium-scale entrepreneurs, communities and health workers
I.C.2.b.(3)(a) Priority: (1) Essential
I.C.2.b.(3)(b) U.S. researchers: None
I.C.2.b.(3)(c) HC researchers: Sefa-Dedeh, Sakyi-Dawson, Tayie
I.C.2.b.(3)(d) Methodology: In collaboration with the National Board for Small Scale Industries, The Food Cluster Group, the Nutrition Division of the Ministry of Health and Non-governmental organizations cowpea processing technologies will be extended to entrepreneurs and community development practitioners.
Specific Methodology--Dissemination to Communities: Sensitization as well as training programs were carried out in the following rural communities in the Greater Accra District: Maanpehyia, Otinibi and Damfa.

A technical team of CRSP met the elders and members of the above named communities and educated them on the importance of good nutrition. The cowpea fortified maize dough product was introduced to them. The community was trained in the production and utilization of the product. The following information was conveyed to the members: -Information about:

- The six food group
- The need to eat balanced meals (need for a balanced diet)
- The importance of high protein diets to infants especially those being weaned
- Reasons for plant protein utilization (cowpea fortification of maize dough)
- Steps involved in the preparation of cowpea fortified maize dough – measuring, dehulling and preparation of the dough.

After the demonstration session, porridge was prepared and served to those present at the meeting. This was done to ascertain their acceptability and perception of the product. At the end of the demonstration, the people promised to use the product especially when the previous ones introduced into the community (iron-fortified cowpea maize dough) brought tremendous improvement in the health of their children.

Dissemination to Small-, Micro- Enterprises: The CRSP team prepared a training manual on the processing of cowpea-fortified fermented maize dough. This was widely distributed to the public. Two important activities were held and this offered the CRSP team to share CRSP technologies with Entrepreneurs. These were the Partners' Day held at the University of Ghana. This brought the food industry to the University campus. Various entrepreneurs attended and were taught how to produce cowpea-based foods. The CRSP team participated in the 5th Ghana Industry and Technology Fair. This 10-day exhibition showcased various technologies and products and brought together participants in industry.

I.C.2.b.(3)(e) Anticipated (1 year) results of activity: An increased use of cowpea in micro-, small- and medium-scale food processing. An increased use of cowpea for improving the nutrition and health of children.

I.C.2.b.(3)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Volume of cowpeas processed and utilizes increased in the urban and rural communities	2-5 years	Increased volumes assessed by surveys

I.C.2.b.(3)(g) Budget:

UGL	$10,000
Total (Direct costs only)	$10,000

I.C.2.b.(3)(h) Major changes: There were no major changes in the year. The Nutrition Officer with the Ministry of Health in the Central region was involved in an accident which affected his participation in the work.

I.C.2.b.(3)(i) Progress during past year: The project entailed the sensitisation of communities on the importance of good nutrition, training of women and entrepreneurs in the production of a simple high-energy protein food - cowpea fortified fermented maize dough to improve nutritional status. The essence of this was to encourage the women in the communities to make the product commercially and to widen the utilisation of the product. Small-scale enterprises are expected to be developed.

I.C.2.b.(3)(j) Current status of research: The training program will continue in communities beyond Greater Accra Region. Training manuals will be distributed to women attending outpatients departments (OPD's) in health institutions and the information will also be extended to entrepreneurs interested in the production of the dough.

I.C.2.b.(3)(k) Documented impact: The volume of cowpea processed and utilised in urban and rural communities will increase.

I.C.2.b.(4) Activity #4: Low-fat akara for U.S. markets

I.C.2.b.(4)(a) Priority: (2) High priority

I.C.2.b.(4)(b) U.S. researchers: Hung, McWatters

I.C.2.b.(4)(c) HC researchers: None

I.C.2.b.(4)(d) Methodology: Akara balls prepared from cowpea meal have higher oil content than akara prepared using the traditional wet milling process. A modified akara preparation method using wet blending of cowpea meal will be used. Oil content and quality of akara prepared using the traditional process, cowpea meal, and a modified wet blending method will be compared. Effect of different re-heating methods of partially cooked frozen akara prepared from the three above mentioned methods will also be evaluated.

Specific Methodology: In the FY00 annual report, we reported the successful development of a pilot-scale method for production of akara. This method uses 500 grams of dry cowpea seeds per batch, a 3-hour soak, and wet milling. Paste produced by this method has a suitable moisture content and viscosity for whipping and dispensing into hot oil and produces highly acceptable akara balls with a spongy, bread-like texture, and crisp outer crust. This method was used in preliminary trials to investigate cooking method and formulation modifications for reducing the final oil content of akara

I.C.2.b.(4)(e) Anticipated (1 year) results of activity: Information obtained from this research will identify processing parameters and re-heating methods of producing akara with low-fat content but still maintain high eating quality.

I.C.2.b.(4)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
A low cost, high nutritious product will be available for U.S. consumers	2-3 years	Adoption of the products and/or process by U.S. food service industry

I.C.2.b.(4)(g) Budget:

UGA Personnel	$16,120
Total (Direct costs only)	$16,120

I.C.2.b.(4)(h) Major changes: The only change in this activity has been the use of wet milled paste instead of cowpea meal.

I.C.2.b.(4)(i) Progress during past year: The fat content (dry basis) of akara prepared by the pilot-scale method (control) and fully cooked in oil is 32%. Process conditions and their effects on fat content are shown in Table 1. Partial cooking to set the shape of the paste was accomplished by microwaving, steaming and frying. Of the samples that were finish fried immediately after partial cooking and cooling (treatments 1,2,3), all contained less fat than the control with treatment 3 having the greatest reduction (8.8%). When a freezing step was introduced after partial cooking and the final cooking was by frying (treatments 4,5,6) fat content increased to 43.8-44.7%. When partially fried, frozen and finih cooked by microwaving (treatment 7) or oven baking (treatment 8), fat content of akara was either very similar to the control or about 5% less.

Table 1. Effect of cooking method on fat content (% dry basis) of akara

Trt. 1.	Partially microwaved/cooled/finish fried	26.2
Trt. 2.	Partially steamed/cooled finish fried	30.2
Trt. 3.	Partially fried/cooled/finish microwaved	23.2
Trt. 4.	Partially steamed/frozen/finish fried	44.2
Trt. 5.	Partially microwaved/frozen/finish fried	43.8
Trt. 6.	Partially cooked in convection-microwave oven/frozen/finish fried	44.7
Trt. 7.	Partially fried/frozen/finish microwaved	31.1
Trt. 8.	Partially fried/frozen/finish oven baked	27.2

Recent reports in the literature have shown that addition of gelatinized rice flour or precooked, acetylated rice starch produces significant reductions in oil uptake of fried doughnuts. In order to maintain consistent dough consistency, however, adjustments in the water content of the formulation are necessary. Three starchy ingredients were evaluated for their effectiveness in reducing the fat content of akara. Hylon VII (corn starch), Crisp Film (modified corn starch) and extruded (gelatinized) cowpea flour were used in preliminary trials. Frying time was two minutes for all treatments. Results are reported in Table 2. Fat content decreased consistently as starch level increased. The 10% level was judged to be the most promising with its combined fat reduction capability and maintenance of desirable paste handling quality as well as sensory attributes. Sensory evaluation of akara processed with 10% of each of the three starch ingredients has just been completed. Untrained panelists who are regular consumers of fried foods judged product quality and acceptability. Data are being analyzed currently.

Table 2. Effect of starch ingredients on the fat content of akara (% dry basis)

5% Hylon VII (63% paste moisture)	30.9
5% Crisp Film (63% paste moisture)	26.7
5% Extruded Cowpea Flour (63% moisture)	26.7
10% Hylon VII (61% paste moisture)	23.3
10% Crisp Film (61% paste moisture)	23.4
10% Extruded Cowpea Flour (61% paste moisture)	18.7
15% Crisp Film (60% paste moisture)	18.9
15% Hylon VII (64% paste moisture)	25.5
15% Hylon VII (60% paste moisture)	21.1

I.C.2.b.(4)(j) Current status of research: This work is proceeding on schedule. By Spring, 2002, physical-chemical and sensory tests will be completed on akara processed with several fat-reduction strategies. The most promising cooking method and modified formulation to incorporate the use of pre-gelatinized starch will have been identified in this phase of the research.

I.C.2.b.(4)(k) Documented impact: Akara loses paste moisture during frying; the water is replaced by oil and results in a 32% fat end product. Excessive fat consumption is known to cause health problems. Modifications in cooking method and formulation are strategies which appear to be effective in reducing the fat content of akara without sacrificing desirable eating quality. Implementation of such strategies will facilitate the commercialization of cowpea-based foods for consumers who prefer to limit fat consumption.

I.D. Constraint #4: Socioeconomic Research Insufficiently Integrated with Production and Utilization Research

I.D.1. Research area: Economics of cowpea utilization

I.D.1.a. Background: The adoption and use of cowpea utilization technologies should be linked with a clear understanding of the socioeconomic and other critical factors that may influence outcome.

I.D.1.b. Proposed research area workplan and subsequent annual progress report:

I.D.1.b.(1) Activity #1: Economic analysis of cowpea processing

I.D.1.b.(1)(a) Priority: (2) High priority
I.D.1.b.(1)(b) U.S. researchers: Nyankori
I.D.1.b.(1)(c) HC researchers: Sakyi-Dawson, Sefa-Dedeh, Tano-Debrah, Gadegbeku, Asuming-Brempong and Tano-Debrah
I.D.1.b.(1)(d) Methodology: The cost-technology profiles of cowpea processing alternatives in Ghana initiated in FY 00 will be continued to cover all products developed.
I.D.1.b.(1)(e) Anticipated (1 year) results of activity: A comprehensive cost-itemized description of cowpea processing activities in Ghana showing differences and similarities between alternative processing practices, as well as product volume and quality.
I.D.1.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
An increasing number of households and commercial dealers will be using a more cost-effective cowpea processing practice involving lower expenditure, labor and time to produce more and higher quality products within two years. Household time and labor requirements for cowpea processing will be reduced by at least half in 20 percent of urban households within two years		

I.D.1.b.(1)(g) Budget:

UGL	$10,000
Clemson	2,500
Total (Direct costs only)	$12,500

I.D.1.b.(1)(h) Major Changes: None
I.D.1.b.(1)(i) Progress during past year: A framework for an in input-out matrix of technical coefficients for cowpea processing has been completed and standardized to account for local variations in processing procedures. Each product is characterized and defined by a vector of input coefficients reflecting product transformation from the raw cowpea grain to the final processed product. Ongoing work is focusing on sampling to obtain a representative sample of cowpea processors for each product as well as newly developed cowpea products.
I.D.1.b.(1)(j) Current status: The group will conduct a pilot survey for content and procedural verification purposes. By the end of the next reporting period a complete survey and final analysis will have been completed.

I.D.1.b(1)(k) Documented impact: not yet.

I.D.1.b(1) Activity #3: Economic analysis of cowpea processing
I.D.1.b(1)(a) Priority: (1) High Priority
I.D.1.b(1)(b) U.S. researchers: Phillips, McWatters, Chinnan, Hung
I.D.1.b(1)(c) HC researchers: Sakyi-Dawson, Cynthia, Sefa-Dedeh, Tano-Debrah
I.D.1.b(1)(d) Methodology: The survey covered thirty respondents comprising fifteen households and fifteen commercial operators. These people were selected from the following areas: Achimota, Ashaley-Botwe, Atomic, Haatso, Legon, Maamobi, Madina, Nima, Okponglo and Tesano The households were selected using the purposive-sampling method. This

method was used based on the assumption that with good judgement and an appropriate strategy, the researcher can pick an individual that is satisfactory in relation to ones research needs. The commercial operators were selected using systematic random sampling method. This involved the selection of the first commercial operator producing cowpea-based products in an area and subsequently, every other producer till the sample size was attained.

Data collection technique: To help achieve the objectives of the study, an interview schedule was used. A written guide indicating questions to be asked and in what order was used when interviewing the respondents. This was most suitable especially because of the educational level of the respondents. It was also used since the researcher could clarify items to respondents individually.

Results of Activity–Characteristics of respondents: All the respondents except one were females confirming the dominant role of women in food processing in Ghana. They play a significant part in post-production operations of agricultural commodities. This may account for a majority of respondents interviewed being women. Fifty-three (53%) were married and 47% were single.

Majority of the respondents (77%) were between the ages of 20 – 40 years. This age group (20 – 40 years) not only show high productivity but is also the group most likely to be having children. Twenty percent (20%) were more than forty years and 3% less than twenty years. Food processing is found to be one of the economic activities preferred by women in this age group (20 – 40 years). This is partly because they can feed their children with some of the food and still make economic gains. This is one activity that does not have a very high capital outlay and its returns are generally fast. Table 1 shows the age distribution and educational level of the respondents.

Table 1: Age distribution & educational levels of respondents:

Age	Educational Level											
	None		Primary		Secondary		Tertiary		Commercial		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
< 20yrs	-	-	-	-	1	3	-	-	-	-	1	3
20 - 40 yrs	6	20	7	23	7	24	2	7	1	3	23	77
> 40yrs	3	10	2	7	-	-	1	3	-	-	6	20
Total	9	30	9	30	8	27	3	10	1	3	30	100

The educational level of respondents is generally low. Most of them (60%) had primary education or no education, 27% had secondary education, 10% tertiary education and 3% commercial education. The generally low level of education has implications when one especially considers policies and strategies important for improving this important sector in the Ghanaian food system (commercial processing of cowpea). Women control the traditional food processing system so a better understanding of management science and simple techniques in food processing will be one important factor for effective improvement in this sector and this may be affected by their low educational level.

Thirty percent (30%) of the respondents were from the Northern part of Ghana, 26% were Ewes, 20% were Akans, 10% were Fantes', 7% Togolese and 7% Ga's.

Sixty percent of the respondents (60%) had more than five people in their household, 37% had between three to five people in their houses and 3 % had less than three people in their household.

Eighty percent (80%) of commercial operators have been selling cowpea -based products for more than five years whiles 20% have sold it for between three to five years. With households on the other hand, 67% have been preparing cowpea-based products for between five to twenty years whiles 33% have been preparing cowpea-based products for more than twenty years.

Where cowpea is processed: Cowpea is processed in households. Commercial operator's process it in their houses before sending it out for sale either in their kiosks, spots or stalls.

What cowpea is processed into: Cowpea is processed into a variety of dishes with households preparing a combination of more varieties than commercial operators. Most households interviewed (80%) prepared more than one cowpea-based product. They produced a combination of these cowpea based products namely waakye (67%), beans stew (53%), fried plantain and beans (40%), gari and beans (33%), koose (13%), tubani (7%), and apapransa (7%). Commercial operators however sold three different cowpea products namely, waakye (46%), gari and beans (27%) and koose (27%). None of them sold more than one cowpea-based product.

An analysis of the questionnaire revealed that to an extent the tribe of an individual not only influenced what they sold but what cowpea –based product they consumed. Waakye for instance was a product consumed by all tribes interviewed (Akans, Ewe's, Northerners, Fante's Togolese, Ga's). With the exception of the Northerner's, Gari and beans was consumed by all tribes interviewed. The Ewe's, Northerners and Ga's consumed Koose. Only a Northerner consumed Tubani.

Table 2 further revealed that although Waakye is sold by all tribes interviewed, it was mostly sold by Northerner's (20%). Koose is also mostly sold by Northerner's (20%) whiles Gari and beans is mostly sold by Ewe's (20%).

Table 2: Cowpea-based products sold by various tribes.

Tribe	Cowpea – based products							
	Waakye		Gari & Beans		Koose		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Akan	1	6.7	-	-	-	-	1	20
Ewe	1	6.7	3	20	-	-	4	27
Northerner's	3	20.0	-	-	3	20	6	40
Togolese	1	6.7	1	6.7	-	-	2	13
Ga	1	6.7	-	-	1	6.7	2	13
Total	7	46.8	4	26.7	4	26.7	15	100

It can therefore be concluded that the tribe of households and commercial operators influenced what cowpea-based product they consumed or sold.

How much and how often cowpea is prepared: Majority of households (73%) consume between 1-2 margarine tins (0.45-0.9kg) of cowpea once a week whiles majority of the commercial operators (67%) use between 7-12 margarine tins (3.15 -5.40 kg) of cowpea daily in the preparation of their products (Ref. Table 3).

Table 3: Quantity of cowpea consumed

Frequency of use	Quantity (Kg)									
	Households						Commercial Operators			
	½ Margarine tin or less (<0.225kg)		1-2 Margarine tins (0.45-0.9kg)		3-6 Margarine tins (1.35-2.7kg)		7-12 Margarine tins (3.15-5.4kg)		More than 12 Margarine tins (>5.4 kg)	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Daily	-	-	-	-	-	-	9	60	5	33
Every other day	1	7	1	7	-	-	-	-	-	-
Twice weekly	-	-	2	13	-	-	-	-	-	-
Weekly	2	13	5	33	1	7	-	-	-	-
Fortnightly	-	-	1	7	-	-	-	-	-	-
Only on Saturday's	-	-	-	-	-	-	1	7	-	-
Except Sat. & Sun.	-	-	-	-	-	-	-	-	-	-
Except Sunday's	-	-	-	-	-	-	-	-	-	-
Monthly	-	-	2	13	-	-	-	-	-	-
Total	3	20	11	73	1	7	10	67	5	33

Active month(s) of processing: Whereas 100% households consumed cowpea throughout the year, there was a different picture with the commercial operators.

- Forty-seven percent (47%) of commercial operators indicated that they processed cowpea throughout the year.
- 20% sell through out the year but indicated that sales were less active during the Ramadan (Moslem fasting period).
- Thirteen percent (13%) could not tell when their active month of processing.
- Seven percent (7%) indicated that with the exception of Saturday's and Sunday's there was active processing throughout the year.
- With the exception of Sunday's, 7% sold their products throughout the year.
- Thirteen percent (13%) who sold near schools indicated that their lean sales was when school was on vacation and their peak season was when school was in session.
- Seven percent (7%) indicated that their lean sale was when maize and yam had been harvested. When these were not in season, her production level increased.

Who processes cowpea: Ninety-three percent (93%) of households made use of self-labor; while 7% used a combination of family labor and self-labor.

Most commercial operators (67%) made use of extra labor in addition to self-labor. Forty-seven percent (47%) used a combination of self-labor and hired labor, 20% used a combination of self-labor and family labor and 33% used only self-labor. Commercial operators need extra labor because they produce larger quantities of products than households. After processing, however, they sell their produce themselves. An important characteristic of processing by the women in Ghana is the contribution of processing and retailing of the processed products by the same person. All commercial operators retailed the products they processed since their production level was low.

Resource utilization: It was difficult obtaining itemized cost of cowpea processing. Most processors and even households could not give any good estimates because they bought in bulk and just used adequate quantities for a particular meal. Generally, also commercial operators did not keep track on expenditure but were only interested in knowing whether they made a profit or not. To calculate this they deducted the bulk amount of money spent in purchasing items from what they derived after sales. So they were able to tell in sum how much they spent in preparing the meal, but had difficulty breaking it down into smaller units. An average of about ¢15,000 profit was made daily on the sale of their produce.

Method of Processing: The methods of processing used are:
- Beans stew - Boiling
- Gari & beans - Boiling
- Waakye - Boiling
- Koose - Soaking, milling, pasting, frying
- Tubani - Soaking, milling, pasting, steaming

These processes may affect yield, profitability, and the efficiency of the process as well as the nutritional quality of the resulting product. Some of these processes (like pasting) are strenuous and may sap the energy of the commercial operators who have to produce on a large scale. This may account for the reason why commercial operators producing koose or tubani are less than those producing waakye or gari and beans.

Chemicals: The predominant chemical used in the boiling of beans is salt peter (locally called 'kawe'). Seventy percent (70%) of the respondents indicated they used salt peter and salt in the preparation of their dishes. Twenty-three percent (30%) used only salt.

Majority of the respondents (70%) who used chemicals in the preparation of their food could not approximate the cost nor the quantity of the chemical used. This is because they buy in bulk and just use small quantities for a particular meal. Out of those who could approximate the cost of chemicals used, 30% indicated they used ¢100 worth for a meal, 10% used ¢200 worth, 7% used ¢50 worth, 7% used ¢250 worth, and 3% used ¢500 worth.

Fuel: Majority of the respondents (53%) used charcoal in the preparation of their meals. Thirty-four (34%) used firewood, 7% used gas and 6% used either gas or charcoal. Fifty percent (50%) of respondents (mainly households) were unable to cost the fuel used in the preparation of their meals. This was again due to the fact that they bought in bulk and used just enough for a particular meal. The commercial operators were however able to cost it better than households.
Out of the fifty percent (50%) who could cost the amount of fuel used, thirty percent (30%) indicated they used more than ¢1000 worth of fuel in the preparation of their meals, 13% used less than ¢1000 worth and 7% used ¢1000 worth.

The use of mainly charcoal as the energy input (in processing especially) results in the products being expensive. In some cases boiling has to be done for very long periods and these affect the total cost of production which ultimately affects the final cost of the product and the number of consumers who would patronize these products.

Labor: The forms of labor used were self-labor, hired labor and family labor. Ninety-three percent (93%) of households made use of self-labor; whiles 7% used a combination of family labor and self-labor.

Forty-seven percent (47%) of commercial operators indicated they used a combination of self-labor and hired labor, 33% used only self-labor and 20% used a combination of self-labor and family labor. Respondents did not pay family labor in cash but often rewarded them in kind. They obtained their wages in the form of some of the processed product. Out of those who used hired labor, 20% could not mention how much it cost, 13% paid their hired labor less than ¢4000 daily, 3% paid ¢4000 daily and 11% paid more than ¢4000 daily. The traditional process require high physical energy input but because of the high cost of hired labor, processors rather prefer producing low quantities of their product so as to avoid this extra cost of labor. If some of these steps of processing can be improved or eliminated and replaced by less tiring ones, yields will go up.

Supplies: All respondents (100%) had an idea about the supplies used. Eighty seven percent (87%) of them could not cost the items used. The remaining 13% could cost it but had difficulty doing it. They gave costs ranging between ¢400 and ¢36,000, with commercial operators having higher approximations.

Time: Most respondents (53%) could not approximate the time used in cooking. Forty-seven (47%) were however able to approximate the time used in the preparation of their meals. Out of the 47% who could approximate the time used, 24% indicated they used about one hour in the preparation of cowpea based products, 23% used more than one hour. Long cooking time affects fuel use. This increases total cost of production thus discouraging respondents from using or cooking these products. If time and energy input to process can be cut down and at the same time achieve the desired product, the level of production can be increased.

Tools: Although all respondents were able to mention the tools used in the preparation of their products, they were unable to cost them. Some of the tools used include:

- Aluminum cooking pots (used for boiling and frying)
- Cane baskets (used as strainers for frying and for washing cowpea)
- Stirrers/ladles (used to prevent product from becoming lumpy)
- Corn mill (used to mill cowpea)
- Plastic plates and cutlery (used to serve their products)
- Coal pots (by those who use charcoal), three stone fireplace (by those who use firewood) and gas cookers (by those who use gas)

The use of the corn mill to mill their cowpea, is an indication of reduction of labor as compared to the traditional way of grinding on a stone or using of a mortar and pestle.

Water: While 53% of respondents could approximate the cost and quantity of water used, 47% could not. Out of the 53%, thirty percent (30%) could mention the cost but not the quantity of water used whiles 23% mentioned the quantity but not cost. 24% used less than ¢1000 whiles 6% used more than ¢1000 worth. On the other hand, 13% used less than one bucket (less than ¢300), 8% used more than one bucket (more than ¢300) and 2% used only one bucket of water in the preparation of their meals (¢300). (A bucket of water in that part of Accra is sold for ¢300).

Respondents could not cost water mainly due to the fact that processors usually have access to tap water in their homes for processing, and do not consider the cost of use of water until bills are brought at the end of the month. Others do not have the facility so they have to pay each day to fetch water elsewhere. This was the case with processors who were able to cost the amount of water used in the production of their cowpea – based products.

It is worth mentioning that there was no significant relationship between the educational level of respondents and their costing of the cowpea processing process. Irrespective of their educational level, respondents had problems making an itemized cost of the production process.

Where cowpea is purchased: Most of the respondents (93%) of commercial operators and 66% of households) obtained their cowpea from the market. Some of the markets they obtained cowpea from are Madina, Makola, Mallam Atta markets (generally they bought it from the market nearer their places of residence). Seven percent (7%) of commercial operators purchased their cowpea directly from farms. Seven percent (7%) of households buy from supermarkets, and 7% buy from stalls around their houses.

Product disposition: Households generally prepared cowpea products specifically for home use. With commercial operators on the other hand, (80%) sold it locally (that is near their place of residence). Twenty percent (20%) roamed around with the product on their heads within their area. Out of the eighty percent (80%), 67% sold it on tabletops or in stalls, whiles 13% of the sellers had kiosks or spots where they sold their products.

Price of Cowpea: The price of cowpea fluctuated throughout the year. Even in the same month, prices varied from one locality to another. These price variations inadvertently affect the price of products. Majority of respondents (70%) bought cowpea that was sold for ¢1300 or less, 17% bought cowpea sold at ¢1400, 10% bought it at ¢1500 and 3% bought it for more than ¢1500. Commercial operators bought more of the cheaper varieties that end up being of poor nutritional quality due to its weevil infestation.

Step by step description of processing method
Rice and beans (Waakye):

- Water is put on fire and allowed to boil
- The cowpea is sorted to remove all foreign materials
- It is washed and put on fire to boil
- It is allowed to boil for an hour or till it becomes soft
- The rice is then added and allowed to boil slowly
- It is stirred occasionally to ensure that it cooks evenly
- It is served with black sauce (shito) , fish or eggs

Gari and beans (Yoo ke gari):

- Water is put on fire and allowed to boil
- The cowpea is sorted to remove all foreign materials
- It is washed and put on fire to boil
- After boiling for ten minutes, the water is strained and fresh water put on it. This is to

ensure that all weevils and foreign materials are removed from it
- It is allowed to boil for an hour or till cowpea becomes soft
- It is served with either gari, stew or hot pepper, or plantain

Koose:
- Dehull the beans and soak overnight
- Grind the soaked beans into a fine paste
- Mix the paste with onions, salt and pepper
- Add water to form a dropping consistency
- Keep beating the paste until it rises and looks like a cake mixture
- Fry spoonfuls in deep hot oil till golden brown
- Serve hot or cold with porridge and roasted groundnut.

Tubani:
- Soak the cowpea for a few minutes
- Mill it into a fine paste
- Add water to the paste to form a slurry
- Add salt to taste
- Mold it (using special moulds or leaves)
- Steam it.

Beans stew:
- Put water on fire
- Allow to boil
- Sort cowpea to remove debris
- Wash cowpea and put in boiling water
- Add salt petre and allow to boil till soft
- Blend ingredients (pepper, onions, tomatoes, spices)
- Put red oil on fire and add chopped onions
- Pour in blended ingredients
- Allow to simmer till the water content reduces
- Add beans
- Add salt to taste.
- Leave it to simmer for sometime
- Serve with plantain, gari, rice, kenkey etc

Apapransa:
- Roast corn to dark brown color and mill into fine flour
- Boil beans and palmnut separately
- Pound the cooked palmnut and make extract using hot water
- Add momoi, smoked fish, onions, pepper, tomatoes and salt in a pot to extract
- Boil for about 45 minutes
- Add spices and other condiments
- Boil further for 30-45 minutes
- Add roasted cornflour to mixture, a little at a time and cook into a thick paste by stirring.
- Serve hot.

Problems with the production of cowpea based products: Although 45% of commercial operators and 42% of households indicated they did not have any problems with the use of cowpea based products, Table 4 gives a summary of some of the problems respondents indicated they had with the use of cowpea based products.

Table 4: Constraints to cowpea processing

Constraints	Commercial Operators (%)	Household (%)
None	45	42
Weevil infestation	27	29
Flatulence/gas	-	22
Stomach upset/ constipation	-	7
Foreign particles	7	22
Presence of insecticides	7	7
Long cooking time, more fuel/ high cost	7	7
Low patronization of produce causing spoilage	7	-
Low foaming property of certain cowpea varieties	7	-

Weevil infestation was the main problem respondents had with the use of cowpea. The cowpea beetle (*Callosobruchus maculatus walp*) infests cowpea in most cases and they have an effect on food quality and nutrient availability in cowpea. More households (29%) had a problem with insect infestation than commercial operators (27%).

Although no commercial operator mentioned this problem, 22% of households indicated that they were reluctant to use cowpea-based products because it caused flatulence or gas. Seven percent (7%) of households indicated they constipated or had stomach indigestion when they consumed cowpea – based products. (Indigestion is caused as a result of tannins interacting with proteins to form indigestible complexes). This affected their frequency of use of cowpea based products.

Twenty-two percent (22%) of commercial operators and 7% of households indicated there was a lot of foreign particles or debris in the cowpea they purchased and they had to spend a lot of time sorting this out before preparing their meal. This they indicated not only increased the cooking time of cowpea but also made its cooking a bit cumbersome.

Seven percent (7%) of commercial operators and households indicated that they were worried about the residual effect of preservatives on their health. Because of this, they did not consume too much of cowpea-based products and they consumed it less frequently.

Another cause of under utilization of cowpea-based products was the long cooking time required for these products. Seven-percent (7%) of commercial operators and households indicated that it took too long a time to cook the beans thus they used much more fuel than they would use in preparing other meals and this increased their cost of production. The commercial operator indicated that this was not too good for someone preparing cowpea for sale. They explained that this was the reason why less commercial operators prepared cowpea based products for sale.

Commercial operators (7%) also mentioned that because of low patronization, their product did not get finished at the end of the day, so part of it got spoilt and this was not too good for business. They preferred a product that did not get spoilt easily and could be preserved very easily overnight and still look presentable enough to be sold the next day.

Seven percent (7%) of commercial operators also indicated that certain varieties of beans had low foaming properties thus when it was used in the preparation of their product (koose), it did not turn out properly.

Conclusion: Some steps involved in the processing of cowpea - based products are laborious and need to be improved. Some of the tasks take too long a time and need to be shortened if possible. These steps include pasting, boiling cowpea and mixing the ingredients. Already prepared cowpea flour for instance if bought by koose or tubani sellers for the preparation of their product, would reduce the processing time and labor required for processing those products.

In spite of all these drawbacks, processors are able to produce good quality products. But improvements need to be made in processing methods to make processing easier at the same time achieve better quality products.

There is also a need for more education on the keeping of records of expenditure (especially with commercial operators). Workshops could be organized them. At such workshops they could be educated on product control, book keeping and costing as well as other areas of food processing management.

I.D.1.b.(1)(h) Major changes: There have been no major changes in the project.

I.D.1.b.(1)(i) Progress during past year: The study sought to collect data on current cowpea processing practices of commercial operators and households, to come out with a comprehensive cost itemized description of cowpea processing activities in Ghana.

I.D.1.b.(1)(j) Current status of research: The activity has been completed but there is a need for education on food processing management (book keeping, production control, costing etc).

I.D.1.b.(1)(k) Documented impact: An increasing number of households and commercial operators will be using more cost-effective cowpea processing practices involving lower expenditure, labor and time to produce more and higher quality products. Household time and labor requirements for cowpea processing will reduce.

I.D.2. Research area: Field school impact evaluations

I.D.2.a. Background: Baseline and preliminary follow-ups have been conducted for schools held near Tamale, at Wa, and at Damongo. These data have been entered and currently are being analyzed. Preliminary findings were shared at the combined PEDUNE-RENACO-Bean/Cowpea CRSP meeting held in Benin, March 1999. Partial data have been collected on the first CRI Farmer Field Schools (FFS) near Edjura. In the funding cycle for which these monies are being requested, follow-up work needs to be done at Edjura for the completed Cowpea Action Research Sites (CARS) and for the planned new CARS to be held at the same site, as well as for the Bolgatanga Training of Trainers (TOT) (SARI). CRI plans two other new schools in the southern part of Ghana. Preliminary work will have to be conducted at these sites. Preliminary work needs to be conducted for the 6 new schools being planned by SARI. These will be held in the Northern Region, Upper West and Upper East regions of Ghana.

I.D.2.b. Proposed research area workplan and subsequent annual progress report:

I.D.2.b.(1) Activity #1: On-going evaluation of field schools

I.D.2.b.(1)(a) Priority: (1) Essential, but reduce sample if necessary

I.D.2.b.(1)(b) U.S. researchers: VanderMey
I.D.2.b.(1)(c) HC researchers: Abatania, Marfo, Haleegoah
I.D.2.b.(1)(d) Methodology: Longitudinal, panel surveys of representative samples of field school participants, including TOT, FFS, and CARS
I.D.2.b.(1)(e) Anticipated (1 year) results of activity: Information on changes in knowledge, practices and future needs of field school participants
I.D.2.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Reduced and safer pesticide use, improved environmental health of farms, increased consumption of cowpea as a table food and as a weaning food, improved cowpea storage practices and refinement of field school curriculum		

I.D.2.b.(1)(g) Budget:

CRI	$ 3,355
SARI	5,210
Clemson	3,200
Total (Direct costs only)	$11,765

I.D.2.b.(1)(h) Major changes: The only major change has been to refine the original pre-post instrument to accommodate a second follow up.
I.D.2.b.(1)(i) Progress during the past year: Second wave follow up interviews are being conducted with the original sample from Tamale, Wa, and Domongo.

Background: Baseline and preliminary follow-ups have been conducted for schools near Tamale, at Wa and at Domongo. Preliminary findings were shared at the combined PEDUNE-RENACO-Bean/Cowpea CRSP meeting in Benin. Partial data have been collected on the first CRI Farmer Field School near Ejura.

The initial follow up of Farmer Field Schools conducted at Tamale, Wa, and Domongo was based on intensive, structured interviews with 28 participants. These participants represented approximately one-third of all participants in the three schools (as per agreed upon protocol).

Areas of impact to be measured or otherwise assessed include changes in knowledge, farming practices, and chemical use and handling. In addition, changes in cowpea consumption (table and weaning food) and changes in cowpea production and profit are inventoried.

Among farming practices before and after the Field School, the following showed positive and statistically significant[1] changes: tilling in, rogueing out, using cover crops, weeding, composting, mulching, scouting, and using resistant varieties. There was no real change in intercropping. Since this is a traditional practice, rates were already high. The other traditional practice in the inventory was rotating crops. While there was a slight increase before and after the field schools, the difference was not statistically significant.

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[1] Statistically significant in this study refers to $p = .001$. T-tests were used on the items inventoried pre and post Farmer Field Schools. For the full report, contact Dr. Brenda J. Vander Mey, Clemson University, Brackett 132, Box 341356, Clemson, SC USA 29634-1356. E-mail: vanmey@clemson.edu.

Positive and statistically significant changes were found with the following chemical practices: not using containers for food stuffs, applying only at recommended times, covering the body while using chemicals, protecting the face, protecting the hands, and using only recommended chemicals. Statistically significant improvements were not found with the following: cleaning and storing chemicals according to specifications, storing away from animals and humans, getting chemicals only from the recommended dealers, and using only the recommended amounts of chemicals.

In terms of knowledge before and after field school training, there were notable positive and statistically significant changes. Before the field schools, most participants could not identify any beneficial insects of cowpea. After the training, participants on average could identify four such beneficial insects. Prior to the training, participants on average could name one pest insect of cowpea. After the training, participants could readily name 4 or 5 such insects. Other positive and statistically significant changes in knowledge included: identifying which cowpea varieties are resistant ones; awareness of hazards of chemical use; ability to calculate yield losses; understanding of pest-predator relationship; use of the threshold concept; understanding and ability to explain growth requirements, disease symptoms, and scouting.

Open-ended comments by participants revealed that the schools had taught them about using neem as a natural alternative to synthetic chemical control of cowpea pests. Most participants emphasized that it was through this training that they became more sensitive to the timing of weed control, protecting their bodies while handling or applying chemicals, and differentiating insect pests from beneficial pests.

There were no statistically significant changes in consuming cowpea as table food or using it as a weaning food among this sample of participants. Overall, there is seasonal variability in cowpea consumption. Nonetheless, after training, fewer participants were only rarely eating cowpea, and more participants were consuming cowpea on a regular, daily basis. The change, though positive, did not reach a statistically significant level.

After the field school, average yield per acre was 3.36 bags, whereas prior to the field school the mean yield was 2.62 bags. Participants attributed this higher yield to the use of neem, timelier pest control, more timely weeding, timely planting, and scouting.

There was a decrease in the amount of cowpea, on average, that was sold pre and post field school. Before the field school, participants sold on average 3.61 bags of cowpea. After the field school, the average amount sold was 3.39 bags. The decrease was attributed to greater knowledge about the protein and nutritional value of cowpea (learned in the field school) which prompted slight increases in home consumption and use of cowpea as a weaning food.

Most participants agreed that while neem preparation was very time consuming, it was worth it in terms of money saved (i.e., money not spent on synthetic chemicals because neem is being used) and decreased worry about the harmful effects of chemicals.

Most participants thought that the field school experience had given them more positive attitudes about cowpea as a table food, weaning food, and as a market crop. Several participants also commented that the field school had helped foster an improved sense of self worth, because they had become more knowledgeable and also had become more active decision makers. In addition, a number of the participants indicated that the follow up interview itself was helpful in refreshing their memories about what they had learned.

At the time of the initial follow up, 82% of the participants were or had been training others as a result of the field school. On average, those training others had trained 11 others, most of whom were farmers.

Most participants wanted to continue training others, but needed to have some infrastructure in place to do so. This infrastructure would include some printed materials, shake cloths, hand tools, seed, and so on as had been used by the school trainers.

The third wave of data from these participants currently is being collected. Although not all interviews are completed at this writing, it appears that the participants have continued to train others, but feel constrained because of lack of infrastructure. They also would like refresher sessions.

Follow up with the sample from Ejura has not yet occurred.

I.D.2.b.(1)(j) Current status of research: Due primarily to lack of adequate funds, not all field schools being conducted are also being studied for impact. However, that the second wave of follow up is occurring at the three previously mentioned sites is positive and gives us the longer view of impact of these schools.

I.D.2.b.(1)(k) Documented impact: Participants see the follow up interviews as having a positive impact on their recall of field school materials. The study itself reveals areas where field schools have positive and statistically significant impacts on participant knowledge, farming practices, cowpea consumption practices, and chemical handling and storage practices.

I.D.3. Research Area: Regional cowpea marketing and demand studies

I.D.3.a. Background: Cowpea price and quality data are being collected in Cameroon, Nigeria, Niger, Ghana, Mali and Senegal with the same methodology to insure comparability of information across countries. Data collection start in Sept., 1996, in Cameroon and will be completed at the end of this fiscal year. In the other countries data collection began as follows: Ghana, Aug. 1997; Senegal, Jan. 1998; Nigeria, Nov. 1998; Mali, Aug. 1999; Niger, Sept. 1999. To provide reliable estimates a data series of at least 3 years, and preferably 4 years, is needed. Preliminary analysis of the data in Cameroon and Senegal indicates that consumers there clearly prefer larger grain size. In northern Ghana consumers seem to prefer white cowpeas with black eyes. In Senegal results seem to show consumer taste preferences for certain black speckled local varieties. In Cameroon there is some evidence that female merchants are able to sell a slightly higher prices, probably because they sell in small quantities for immediate consumption.

In addition to completing the data in Ghana, Senegal, Nigeria, Mali and Niger, we need additional data for consumer preferences in urban consumption centers, and it would be useful to incorporate cowpea chemical analyses, especially sucrose levels, into the hedonic pricing analysis. Currently, the only major urban centers in non-cowpea producing areas are Lagos, Nigeria, and Dakar, Senegal. With cooperation from CRI we should be able to gather data in Kumasi and Accra. The chemical analysis issue has arisen especially in connection with the "sweet cowpea" developed in Cameroon.

Preliminary descriptive studies of cowpea market structure will be completed by the end of the

1999-2000 fiscal year in northern Cameroon, Nigeria, Niger, Mali, Senegal, and Ghana. Work has started at Purdue on a regional cowpea trade analysis model, that will require improved estimates of cowpea supply and demand in each country. At Purdue, Clemson and at INRAN, Niger, econometric analysis will be used to measure the spatial and temporal coordination of markets using data from the cowpea price and quality study, as well as from the Market Information System (SIM).

I.D.3.a.(1) Activity #1: Study cowpea price and quality relationships
I.D.3.a.(1)(a) Priority: (1) Essential
I.D.3.a.(1)(b) U.S. researchers: Lowenberg-DeBoer
I.D.3.a.(1)(c) HC researchers: Faye, Langyintuo, Kushwaha, Kergna, Ibro, Ntoukam
I.D.3.a.(1)(d) Methodology: Cowpea samples are purchased once per month in selected markets in Cameroon, Ghana, Senegal, Nigeria, Mali and Niger. The samples are purchased from randomly selected retail vendors. Characteristics on which data was collected included: price, 100 grain weight, length, width, skin color, eye color, skin texture, insect damage (e.g. number of holes/100 grains), type of seller (e.g. male or female, farmer or merchant). A regression-based hedonic pricing analysis is being used to determine market premiums and discounts for cowpea characteristics.
I.D.3.a.(1)(e) Anticipated results of activity: Market values of various cowpea characteristics (e.g., color, skin texture, insect damage). This information will be used to guide breeding and storage research, as well as forming the basis for cowpea market outreach.
I.D.3.a.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
Cowpeas that better match consumer preferences, hence more consumer satisfaction and higher farm income	Initial impact should be evident by the end of this phase in 2001	Increasing market share for cowpeas with desirable consumer characteristics

I.D.3.a.(1)(g) Budget:

IRAD	$ 2,000
CRI	1,000
SARI	6,000
ISRA	5,000
Regional Facilitator includes:	29,000
Facilitation costs,	
$5,000 ATBU, Nigeria	
$2,000 INRAN, Niger	
$2,000 IER, Mali	
Total (Direct Costs only)	$ 43,000

I.D.3.b.(1)(i) Major changes: none
I.D.3.b.(1)(j) Progress during past year–Ghana: In southern Ghana the cowpea price and quality data collection started in May 2000, continued throughout the reporting period. Data was collected from all the six markets identified for the study - four in the coastal city of Accra, and two in Kumasi. However, the enumerator collecting data from one of the markets in Accra (Nima market) was not able to do so in December 2000 and January 2001.

The data for the period May 2000-August showed that prices per kilogram of seed were generally higher in the Accra markets than the Kumasi markets, even though damage levels could not be said to be higher in the Kumasi markets. The mean market prices for the period ranged from 3480 cedis/kg to 3780 cedis/kg in Accra, and 2780 cedis/kg to 2990 cedis/kg in Kumasi. This represented a difference of at least 25% between the cities. The number of holes/100 seed ranged from 8.78 to 17.85 in Accra, and 11.53 to 11.72 in Kumasi (data covers October 2000 to August 2001). There was no consistent pattern of differences in damage to cowpea between markets, as damage levels differed considerably in terms of intensity between months. Where there were peaks, as in May-June and December, it was for just one or two of the markets in Accra.

White grain accounted for 58% of the 470 samples purchased over the period. Overall, there was just an insignificant slight price advantage of the white over other seed color. The overall mean price per kg across markets was 3466 cedis for the white and 3300 cedis for other seed coat color. The white grains were of larger seed size, on average, with 100 seed weighing 15.87 g, compared to 12.25 for other seed colors. Seed damage was substantially higher in the white than the other seed color. The number of seed with holes had an overall mean of 12.84 and 6.77 per 100 seed for the white and non-white respectively, while the number of holes were respectively 14.95 and 9.27 per 100 seed. It would appear that the seed size is a positive physical attribute. Further analysis through hedonic modeling would be required to establish those factors that are responsible for the at least similar price for white as the other varieties, in spite of the higher level of damage.

It was not possible to measure the relationship between storage method and weevil damage because all the traders followed similar practices. They stored in jute or fertilizer bags and did not use any storage chemical. This may be explained by the fact that the traders in the cities do not store the cowpea for a long time.

Three years of cowpea price and quality data in northern Ghana were completed in August, 2001. The data were collected at Tamale, Wa and Bolgatanga. A complete analysis of the three years of data is being carried out.

Mali: The cowpea price and quality data from two markets in Bamako shows relatively small grains and relatively high bruchid damage levels (Table 1). The 100 grain weight in the Malian samples is 11 to 12 grams, compared to 18 grams in Senegalese and in Nigerian samples, and 16 grams in the Nigerien data. The average number of bruchid holes in the Malian data is 14 to 16 holes per 100 grains, compared to long term averages of six holes in Senegal, seven holes in Nigeria, 14 holes in Ghana and 13 holes in Cameroon. The average damage levels in the Bamako samples is similar to that of samples purchased in Maradi, Niger. Unlike the Maradi samples, the maximum damage levels in the Bamako data are quite modest. None of the Bamako samples have over one hole per grain (100 holes per 100 grains).

Most of the Bamako samples have a rough, white testa and black eye. About 64% have a white testa. About 17% are red. Almost 80% are have a rough skin.

The price range in the Bamako data is from 175 FCFA/kg to 375 FCFA/kg. This is a narrower price range than the Senegalese data, but it should be noted that the Malian data includes only urban markets, while the Senegalese data includes two markets in the principal production area. Most of the cowpea retailers in the Bamako data are male. They have shops or stall which sell a variety of products. Female cowpea vendors are usually producers who come from the countryside with a small amount of cowpea to sell.

Lowenberg-DeBoer and Langyintuo are working with Kergna to implement the hedonic pricing analysis of the Bamako data. The preliminary data suggests an opportunity for the CRSP to work with IER on breeding to increase grain size and storage techniques to reduce bruchid damage.

Table 1. Descriptive Statistics for Cowpeas Purchased in Markets in Bamako, Mali, Oct., 1999 - September, 2001.

Variable	Min	Max	Average	Standard Deviation
Bamako, Medine Market				
Price, FCFA/kg	175	375	240	55.8
100 grain weight, gr.	5	20	12	3.4
Bruchid holes/100grains	1	59	14	12.1
Bamako, Sabailibougou Market				
Price, FCFA/kg	175	375	263	67.8
100 grain weight, gr.	5	20	11	2.6
Bruchid holes/100grains	1	67	16	14.4

Niger: Cowpea price and quality data continues to be collected in Niamey, in the Petite Marché and Wadata Market (Table 2). Data collection was started in the Maradi Central Market in May, 2000. Maradi is Niger’s third largest city. It is located in the middle of Niger's cowpea primary cowpea production area. Many Maradi merchants have close links to cowpea traders in Kano, Nigeria.

About half of the cowpea in the Niamey market has a white testa (49%), slight less than half is red (45%), and most of the rest is white with black speckles. The red cowpea is mostly TN578, a variety developed by INRAN in the 1980s. All varieties have rough skins. The cowpeas with the largest grain size either come from the Ayerou are of Tillaberi Department on the Mali border, or are imported from Nigeria. The level of bruchid damage in the Niamey comparable to that found in Senegal, the lowest bruchid damage site in the CRSP price and quality study area.

About 75% of the cowpea samples purchased in the Maradi market have white testa; on one was red. The remainder was of the speckled variety Oloka. The most striking aspect of the Maradi data is the high level of bruchid damage. The average damage at harvest time in the Maradi samples is higher than the year round average in Niamey (Tables 2 & 3).
The Maradi samples have a higher level of bruchid damage than any other site in the cowpea price and quality studies. This should be an opportunity for CRSP storage technologies.

Cowpea prices in Niamey are always higher than those in Maradi, which is expected since Maradi in the center of a major production region. The minimum price observed in Maradi suggests that the price collapse at harvest is not as severe in Niger, as it is in Senegal. Both Maradi and Sagatta are in the center of cowpea production areas. Both markets used West African FCFA currency. In Sagatta a minimum price of 90 FCFA/kg was recorded, while in Maradi the minimum was 175 FCFA/kg. The hypothesis is that the export market to Nigeria provides a floor under the Nigerien market, while in Senegal the poorly developed cowpea marketing system is not able to absorb harvest time supply.

Table 2. Descriptive Statistics for Cowpeas Purchased in Markets in Niamey and Maradi, Niger, May, 2000-June, 2001.

Variable	Min	Max	Average	Standard Deviation
Niamey				
Price, FCFA/kg	250	500	337	55
100 grain weight, gr.	6	29	16	3
Bruchid holes/100grains	0	22	6	6
Maradi				
Price, FCFA/kg	175	375	253	45
100 grain weight, gr.	12.5	32.2	16.2	2.5
Bruchid holes/100grains	0	143	22	28

Table 3. Average Number of Bruchid Holes in Nigerien Cowpea Price and Quality Samples

Period	Niamey	Maradi
Sept.-Nov.	4	7
Dec.-April	5	19
May-July	7	33
August *	10	

* For Maradi data May-August combined.

Nigeria: Collection of price and quality data in Nigerian markets started in Nov., 1998 and is expected to continue through Oct., 2001. Lowenberg-DeBoer visited Abubakar Tafawa Balewa University (ATBU) 26 Jan. to 1 Feb to work with Shehu Musa on the price and quality data. They did a preliminary analysis of data from Nov. 1998 to Oct., 2000. He visited markets at Gombe and Maiduguri. Details are available in his trip report. As a followup Augustine Langyintuo visited Kano from July 14-20 to provide training in statistical analysis of price and quality data. The focus was on use of "seemingly unrelated" (SUR) least squares to estimate separate hedonic equations for each market. Musa and four other ATBU students participated.

The descriptive statistics show that on average cowpea prices in the Lagos market are about 17 Naira/kg higher than those in Kano and Maiduguri (Table 4). It should be noted that Kano and Maiduguri are in major cowpea production zones. The average 100 grain weight is between 18 and 19 grams. This is similar to data collected in Senegal and larger than average grain size in Ghana, Cameroon and Niger. The bruchid damage in the Nigerian data was relatively low, ranging from an average of 5 holes per 100 grain in Maiduguri to 9 holes per hundred grains in Lagos. The maximum number of holes was 30 per 100 grains in Lagos. This is similar to damage levels observed in Senegal and substantially lower than damage seen in the Ghana, Cameroon and Maradi, Niger markets. The damage level is consistent with the observed low cost and wide spread use of storage chemicals like phostoxin.

The preliminary hedonic results presented in Table 5 show that 90%, 68% and 83% of price variability in Lagos, Maiduguri and Kano, respectively, was explained by the independent variables. The continuous variables are: bowl weight=weight per bowl; grain size = 100 grain weight, grams; number of holes = number of bruchid holes per 100 grains. The dummy (zero/one) variables and conditions under which they take the value A1" are: seed color = 1 if white testa; grain texture = 1 if smooth; eye

Table 4. Descriptive Statistics for Cowpea in Three Nigerian Markets, Nov., 1998- July, 2001

Market	Mean	Standard Deviation	Minimum	Maximum
Price, Naira/kg				
Lagos	46.60	14.04	20.52	77.92
Maiduguri	30.71	9.90	13.99	58.89
Kano	40.18	8.77	19.69	62.24
100 Grain Weight				
Lagos	18.69	3.76	10.48	31.90
Maiduguri	18.58	4.52	9.66	32.23
Kano	18.42	3.38	12.08	31.09
Holes/100 grains				
Lagos	9	6.12	0	30
Maiduguri	5	5.48	0	19
Kano	8	5.33	0	20

color type = 1 if black eye; eye size = 1 if large eye; gender = 1 if vendor female; source of grain = 1 if imported; new or old stock = 1 if old stock and month and year variables which take the value of A1" in the period indicated by the label (e.g. "May" = one in the month of May). The month of November and the year 1998 are used as the point of reference for a date dummy variables.

While consumers in Kano and Maiduguri pay a premium (0.56 and 0.57 naira/kg for each gram of hundred grain weight, respectively) for increases in grain size, it is not statistically significant in determining price in Lagos. Number of holes is not significant in explaining price variability at all three locations. This is not surprising because the damage levels are quite consistently low. White testa attracts a premium in all three markets, but that premium is statistically significant only in Maiduguri where most of the cowpea are red or speckled. In Maiduguri white cowpeas are mainly consumed by people who have immigrated from other areas of Nigeria. Smooth grains are discounted in all three markets, but that discount is statistically significant only in Lagos. Eye size and color, and gender of the vendor do not appear to influence price in these three markets. In Lagos and Maiduguri markets imported cowpeas bring a premium in those markets. In Kano and Maiduguri, old stock attract a premium. Storing grain for resale at a later date attract price premiums as observed with the coefficients of the monthly dummies.

Table 5. Preliminary results from the SUR regression analysis for Nigerian markets, Oct. 1998 to July, 2001.

	Estimated coefficient	T-ratio	Estimated coefficient	T-ratio	Estimated coefficient	T-ratio
Grain size	0.06	0.40	0.56	3.74***	0.57	4.53***
Number of holes	-0.09	-1.14	0.05	0.53	0.08	1.11
Seed color	2.50	0.65	6.76	3.99***	2.67	1.59
Grain texture	-3.70	-2.51**	-1.75	-1.06	-1.04	-0.94
Eye color type	0.63	0.16	-2.30	-1.51	-0.43	-0.24
Eye color size	0.71	0.65	2.22	1.33	-0.49	-0.53
Gender	0.80	0.96	0.19	0.15	0.08	0.11
Source of grain	10.41	5.33***	6.39	2.48***	0.29	0.16
New or old stock	-0.17	-0.18	5.41	3.48***	4.01	3.94***
January	6.44	3.33***	-0.50	-0.20	10.39	6.45***
February	13.77	6.60***	5.57	1.80*	12.54	7.73***
March	21.26	7.60***	7.80	2.19**	18.07	10.63***
April	32.86	11.72***	11.64	3.23***	16.84	6.84***
May	36.44	13.56***	17.03	4.68***	19.57	7.79***
June	35.65	13.06***	20.08	5.46***	21.48	8.65***
July	36.64	13.26***	19.27	5.49***	23.79	9.74***
August	41.30	13.90***	14.33	3.81***	24.89	9.61***
September	41.27	13.93***	16.88	4.49***	19.66	7.55***
October	34.39	13.43***	6.41	2.12**	9.94	4.81***
December	3.61	1.99**	1.56	0.67	6.50	4.42***
Y1999	3.19	1.67*	5.61	2.28**	0.05	0.03
Y2000	-1.46	-0.76	3.43	1.40	-1.64	-1.00
Y2001	3.67	1.74*	7.43	2.72***	0.65	0.34
Constant	63.57	8.12***	35.26	3.52***	47.10	6.60***
Adjusted R-Square		0.89		0.63		0.80

Note: Significance levels: *** 1%, ** 5% and * 10%

Senegal: The cowpea price and quality study continued in six markets in Senegal. The data for the 2000 marketing year (Oct. 2000 to Sept., 2001) is similar to 1998 and 1999 (Table 6). The average number of holes for the 2000 marketing year is slight less than 8 per 100 grains, but can occasionally be over 100 holes per 100 grains. The average weight of 100 grains is about 18 grams. There is a wide seasonal variation in price. In Sagatta in the production zone, prices went as low as 90 FCFA/kg during the 2000 harvest. In Dakar markets the price can rose as high as 500 FCFA/kg. Prices tended to be higher for the 2000 marketing year because the cowpea supply was reduced by a government program which supplied groundnut seed to producers for the 2000 cropping season. As a consequence farmers planted more groundnut and less cowpea. Faye estimated the average cowpea price increase due to the groundnut program varied from 70 FCFA/kg in Bambey to 180 FCFA/kg in

Dakar=s Castor Market. Senegalese consumers prefer cowpeas with larger grain size and they discount those damaged by bruchids. This study will be finalized in Faye's dissertation.

In an effort to better understand the market value of cowpea characteristics, a pilot program was started to measure sucrose levels in the price and quality study cowpea samples. When enough data has been accumulated, the sucrose levels will be included as independent variables in the hedonic pricing analysis. The sucrose test started in June 2001 for samples collected from March, 2001. The test procedure was developed by Murdock at Purdue and carried out by an ISRA technician at the Bambey Experimental Station. Results for the period covering March to May, 2001 are available. The sucrose level found so far varies from 0.12% to 3.7%. This compares to the 6% level found in the sweet cowpea lines developed in Cameroon.

Table 6. Descriptive Statistics for Cowpea in Six Senegalese Markets, 2000 Marketing Year (Oct., 2000 to Sept., 2001).

Market	Mean	Standard Deviation	Minimum	Maximum
Price, FCFA/kg				
Bambey	297	73	140	532
Castor (Dakar)	387	54	200	500
Mpal	238	61	90	360
Nioro	365	58	200	450
Sagatta	250	50	132	333
Tilene (Dakar)	348	68	175	500
All Markets	314	83	90	532
100 Grain Weight				
Bambey	20	2	16	25
Castor	19	3	11	24
Mpal	17	4	11	24
Nioro	17	3	11	22
Sagatta	18	3	11	26
Tilene	18	2	11	22
All Markets	18	3	11	26
Holes/100 grains				
Bambey	9	16	0	98
Castor	4	7	0	40
Mpal	8	9	0	32
Nioro	7	9	0	46
Sagatta	13	19	0	102
Tilene	6	9	0	47
All Markets	8	12	0	102

I.D.3.b.(2) Activity #2: Study structure of cowpea demand and markets, with priority on Senegal, Mauritania, Mali, Ghana, Burkina Faso, Niger and Nigeria
I.D.3.b.(2)(a) Priority: (1) Essential
I.D.3.b.(2)(b) U.S. researchers: Lowenberg-DeBoer
I.D.3.b.(2)(c) HC researchers: Faye, Langyintuo
I.D.3.b.(2)(d) Methodology: Primary data on market structure are being gathered via

interviews of market participants. CRSP price and quality studies will provide information on consumer preferences. Secondary data on cowpea prices and production are being obtained from government statistics, research and customs services. A regional production and trade model of cowpea trade in West Africa will be constructed.

I.D.3.b.(2)(e) Anticipated results of activity: Estimates of cowpea demand growth, costs of production by location, supply, marketing cost and marketing constraints. This information will guide research and extension, as well as being the basis for a cowpea marketing outreach effort.

I.D.3.b. (2)(f) Anticipated impact to which this activity will contribute, time frame and indicators:

IMPACT	TIME FRAME	INDICATOR
Farmers have better markets and more cowpeas available to consumers at affordable prices	Initial impact should be evident by the end of this phase in 2002	Cowpea trade increases throughout West Africa region

I.D.3.b. (2)(g) Budget:

CRI	$1,000
ISRA	1,000
Regional Facilitator	$28,500
includes:	
Facilitation costs,	
$5,000 ATBU, Nigeria	
$1,000 INRAN, Niger	
$1,000 IER, Mali	
Total (Direct Costs only)	$30,500

I.D.3.b.(2)(h) Major changes: None

I.D.3.b.(2)(i) Progress during the past year: Information was collected on cowpea trade and market structure in Senegal, Mauritania, Nigeria, Niger, Cameroon, and Gabon. Lowenberg-DeBoer visited Niger and Nigeria in January, 2001. Langyintuo visited Togo, Benin, Nigeria, Niger, Cameroon and Gabon in June and July, 2001. Faye visited Mauritania in August, 2001. In addition, researchers in Niger and Nigeria did interviews. These efforts resulted in detailed information about marketing costs, volumes and roles played by various people in the markets. The following report provides only an overview of the information collected. The detailed information can be found in Lowenberg-DeBoer, Langyintuo, and Faye trip reports. In addition, the information will be documented in dissertations being prepared by Langyintuo, Faye and Musa (Nigeria).

Gabon & Cameroon: Langyintuo visited southern Cameroon and Gabon in June and July, 2001. He gathered information on Cameroon's bean and cowpea exports, Gabonese imports and marketing margins in Gabon. Details are in his trip report.

There are six ferries regularly making the route from Lome, Cotonou, Douala, Libreville. In addition there are numerous smaller boats that make less regular trips from Douala to Libreville. Langyintuo collected detailed information on the M/V MAHOTHES. This ship usually makes the Lome-Cotonou-Douala-Libreville route twice per month. On a typical trip to Libreville the ship would carry a wide range of food stuffs and consumer goods, including about 10 tons of cowpea grain. The cost of shipping a bag of cowpea is about 10,000 FCFA, not including port fees, such as a phytosanitary certificate. In addition there is the transport charge from the Libreville port to a warehouse in the city.

From Cameroon it is possible to transport cowpeas to Gabon by truck, at least in the dry season. These are usually 25 ton trucks. When conditions are good a truck can make the 1000 km route to Libreville in 2 days, versus the five or more days for ocean shipment. Truckers pay a wide variety of fees and informal taxes (Table 1). The total fees and informal taxes for the trip is 722,000 FCFA or about US$1000. The shippers cost per 100 kg bag of grain is 12,000 FCFA (about US$17.14/bag) from Yaounde to Libreville.

Gabon relies substantially on the imports for all its grains demand. Official Gabonese trade figures show that between 1995 and 2000, an average of 37 billions FCFA was spent on all food imports. An estimated 0.07% (29 million FCFA) of this amount was spent on dry beans (beans and cowpeas).

Table 1. Charges paid by a truck transporting grain between Yaounde and Libreville.

Town/Stop	People paid (or type of payment)					Total
	Customs	Police	Gerndamerie	Phytosanitary	Other	
Cameroon						
Mokolo Mkt.	-	5,000	-	-	-	5,000
Mbalmayo	5,000	-	-	-	-	5,000
Ebolowa	10,000	2,000	2,000	-	-	14,000
Ambam	20,000	4,000	4,000	-	-	28,000
Nguiosi[1]	10,000	4,000	10,000	10,000	15,000	49,000
Gabon						
Nguiosi[2]	50,000	-	20,000	50,000	370,000	490,000
Bitam[3]	30,000	-	10,000	20,000	25,000	85,000
Oyem[4]	10,000	-	10,000	10,000	15,000	45,000
Bibas[4]	10,000	-	10,000	10,000	15,000	45,000
Misiq[4]	10,000	-	10,000	10,000	15,000	45,000
Libreville	5,000	5,000	-	2,000	-	12,000
Total						722,000

Source: Langyintuo, "Trip Report on Summer Research in Ghana, Togo, Benin, Nigeria, Cameroon and Gabon, May - July, 2001, Bean/Cowpea CRSP

Table 2. Official imports of dry beans/cowpeas into Gabon by weight and year (kg)

	1995	1996	1997	1998	1999	2000	Average
Togo	174	-	-	64,160	7,554	98,928	28,469
Niger	20,000	-	-	-	-	-	3,333
Nigeria	-	-	-	-	12,437	250	2,115
Benin	-	1,157	48	-	-	1,909	519
Senegal	-	-	-	90	-	-	15
Cameroon	-	-	-	-	285,728	369,036	109,127
Liban	-	-	-	3,220	1,879	-	850
France	1,002	130	164	420	80	130	321
China	-	277	114	219	-	-	102
Turkey	-	-	-	239	-	-	40
Total imports	21,176	1,564	326	68,348	307,678	470,253	144,891

Source: Ministry of Commerce, Libreville, Gabon

On average annual imports stood at 145 mt. Table 2 indicates that the main sources of dry beans are Cameroon, Niger, Nigeria, Benin, Togo and Senegal in Africa. France and China are important exporters of dry beans to Gabon. It should be noted that imports from outside Africa are all beans while those from African countries besides Cameroon are cowpeas. Cameroon exports both beans and cowpeas to Gabon. It has been estimated that about 30% of all beans exported out of Cameroon is cowpeas. This means that official figures capture about 33 mt of cowpeas imports annually between 1995-2000.

It is important to sound a note of caution about the quantities captured officially. The Gabonese government levies various taxes on grain imports. The amount paid depends on the value of the grains. Grains coming from non-central African countries have higher declared values. For example, a 100 kg bag of cowpeas is valued at 7500 FCFA(and about 10-15% higher for non-central African countries). The customs duty of 30%, 18% VAT, 1.5% computerization tax are then levied on this value. Consequently, importers, especially those importing by trucks, invariably under declare their import quantities. To further reduce the amount of tax to pay, some traders, especially those importing from Nigeria, first transport their grains to Cameroon from where they may export them as grains from Central Africa and thus pay lower taxes. Therefore the declared volume of trade between Cameroon and Gabon may be overestimated by the amount supposedly shipped into Cameroon from Nigeria. Conversely, imports from Nigeria may be underestimated by the shipment to Cameroon that are eventually declared as coming from Cameroon. It was difficult to estimate such volumes.

Ghana: Work on cowpea market structure is completed in northern Ghana, but on-going in southern Ghana. In southern Ghana, the wholesale traders are quite distinct from the retailers. There are male and female wholesalers. Wholesale activities in the Kumasi market are carried out only at the Central market. There are both male and female retailers at the Central market but only female retailers at the Asafo market. The major wholesale market for cowpea in Accra is Malata, and there are both male and female wholesalers. The retail trade in cowpea in all the Accra markets is exclusively cowpea.

All the markets studied in southern Ghana receive cowpea from both foreign and local sources. There is the likelihood that some of the varieties that are identified to be local might be of foreign origin that passed through a local market. Foreign sources of supply constitute 40% of sales. Foreign sources are more important for the Accra markets, where 47.5% of the sample originate from outside Ghana than the Kumasi markets, where 38.4% of the supply is accounted for by foreign sources.

The major foreign sources for the Accra markets are Burkina Faso, Niger, Nigeria and Togo. Burkina Faso and, to some extent, Niger are the major foreign sources of supply to the Kumasi markets. The major local sources for Accra are Akatsi, in the coastal savanna, Ejura and Techiman in the middle transition belt, and Tamale and Bawku in the northern savanna.

Mauritania & Sénégal: Faye visited Nouakchott, Mauritania, July 25 to August 1, 2001, to collect information on cowpea production and marketing in that country. The details are found in her report, "Bean/Cowpea CRSP Socio-Economic Activities in Senegal, 2000-2001". Official statistics show that cowpea production in Mauritania from 1992 to 2000 varied from 7,000 MT to 22,000 MT per year, with an average of about 17,000 MT annually. Most of the cowpea is produced by black Mauritanian farmers in areas near Kaedi, close to the Senegal River using traditional production methods, without fertilizer or pesticides.

The cowpea marketing system in Mauritania is similar to that of Senegal. Mauritanian wholesalers in Kaedi buy cowpea from farmers and assemble it in bags for shipment to Nouakchott where it is stored until use. Senegalese merchants also ship cowpea to Nouakchott where it is stored in an area near the Central Market and sold by Senegalese retailers. Many Senegalese traders send "small" 50 kg bags of cowpea on vegetable trucks from Mekhe, on the west edge of the "Peanut Basin". The bags of cowpeas are packed in with the vegetables to avoid taxes at the border. In spite of the best efforts of traders to avoid taxes, some 61 MT of cowpea were recorded crossing the border at Rosso, Mauritania, from Oct., 2000, to Jan., 2001. In Nouakchoutt most merchants store cowpea in steel drums the same as in Senegal. Some merchants store cowpea in bags mixed with hot pepper powder.

Two market categories of cowpea were observed in the Nouakchott markets: white and black (really gray). Retail prices range from 300 FCFA/kg to 800 FCFA/kg depending on the season. Merchants said that the white cowpea typically sells for a premium because it is used for a sandwich filling. Cowpea is cooked with oil, tomatoes, and spices to make a sandwich filling eaten for breakfast or latter in the day. Faye visited three "cracker" ("biscuits" in French) factories in Nouakchott, None of these factories use cowpea in their product. They say their ingredients come from France or Saudi Arabia. Merchants who sell the Mauritanian crackers in Senegal often claim that they are made from cowpea; apparently this is false advertising designed to convince Senegalese consumers that the crackers are a local product.

Niger: - INRAN/DECOR researchers conducted in depth interviews in the Zinder market to better understand the structure of the cowpea market there. Zinder is Niger's second city and traditional capital in precolonial and early colonial times. Zinder is also in Niger's primary cowpea production zone.

Five groups of cowpea varieties were distinguished in the Zinder market:

1) Dan Bassassa - an old improved variety (TN-88-63) which is disappearing. It has a white testa. Growers do not like it because it has small, hard grains, and low forage production.

2) Oloka - a speckled variety appreciated for local consumption because it has a sweet favor, but exporters from Zinder prefer white cowpea.
3) Local long cycle white varieties - Sababba Sata, Dan Tanout and Farin Waké.
4) TN578 - red cowpea
4) Bakin Waké - black cowpea

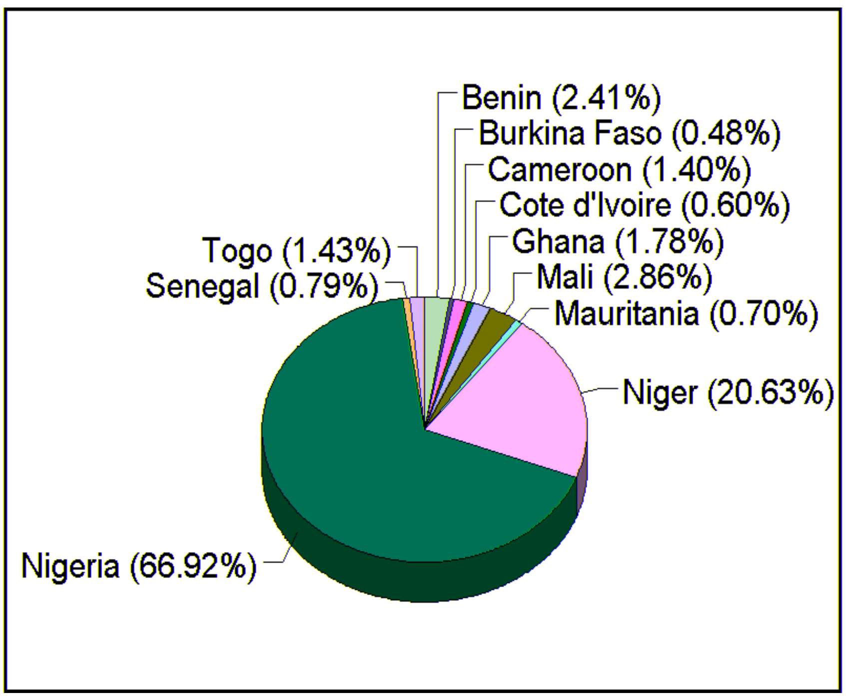
Food vendors who produce kossai prefer the white varieties because they say that it produces more final product from the same quantity of raw grain. They said that two bowls (tia) of the white variety produce the same quantity of kossai as three bowls of Oloka.

Table 3. Costs for Various Steps in Cowpea Marketing in Zinder, 2000

Item	Amount, FCFA/kg	Notes
Purchase sacks	2.5	250 FCFA for 100 kg sack
Fill sacks	0.5	50 FCFA for filling 100 kg sack
Transport from Village to Collection Points	8.0	20 FCFA/tia for 20 km distance
Transport from Collection Points to Zinder	5.0	12.5 FCFA/tia for an average distance of 150 km.
Loading or Unloading Trucks	0.5	50 FCFA for 100 kg sack

Sources: FAO and national statistics from various countries

Figure 1. Percentage of West African Cowpea Production by Country



Storage is mainly done by wholesalers who buy at harvest time and may store a year or more waiting for higher prices. Several wholesalers have warehouses that will hold 1000 to 1500 bags (10 to 15 MT). One recently built a warehouse to store 5000 bags (50 MT). Most wholesalers use storage chemical, usually phostoxin.

The structure of the local cowpea market is quite complex. Producers, wholesalers, retailers, cooperatives all play a part. Cost of various market operations is well defined (Table 1). The export market is quite structured, with about 30 merchants active in this market, though these exporters are not registered with the local Chamber of Commerce.

Key cowpea marketing constraints in the Zinder region include:

1) lack of formal market organization and as a consequence little recognition for the importance of the cowpea trade in the Nigerien economy,
2) dependence on Nigerian markets - when Nigerian markets are disrupted, as they have been recently by ethnic conflict, this caused major problems for Zinder merchants,
3) lack of market information - storage is profitable only for those who have access to market information,
4) heterogentity of grains - colors and varieties are frequently mixed,
5) weak local demand, and
6) storage problems - cost of chemical treatment is high and over treatment is frequent.

Nigeria: Musa, Kushwaha, Langyintuo, and Lowenberg-DeBoer worked to characterize the cowpea market in Nigeria during the 2000-2001 fiscal year. The detailed characterization will be part of Musa's PhD. dissertation at ATBU. The most striking feature of cowpea markets in Nigeria is the scale. The top six cowpea producing states (e.g. Kano, Bauchi, Sokoto, Yobe, Borno, Katsina) on average produce over 100,000 MT annually. These states each produce more cowpea than any West African country, except Niger. All of the main cowpea producing states in Nigeria are in the north on the border with Niger. Available statistics suggest that Niger and Nigeria together produce over 85% of the cowpea in West Africa (Figure 1).

Another example of the scale of Nigerian markets is the market in Gombe, in eastern Bauchi State. Lowenberg-DeBoer and Musa visited this market on Feb. 28, 2001. It is one of several middle rank Nigerian cowpea markets. Merchants there said that they had 40,000 MT of cowpea on hand for immediate sale. Judging by stacks of bagged cowpea under tarps in the market, this was a realistic assessment, not just an idle jest.

Based on interviews with merchants and market administration, Langyintuo estimated that about 50 to 100 large-scale, independent grain and cowpea traders were operating in Dawanau market in Kano which is thought to handle the largest volume of cowpeas. About 10 specialize in cowpeas from Niger; either they travel there to bring the grains or command the grains from there through an agent. In fact, cowpeas dominate grains marketed in Dawanau, constituting about 50% of all grains marketed. It is believed that maize accounts for about 15-20% of the trade, sorghum slightly under 10%, millet and wheat each 10-15%, and rice negligible. The main sources of capital are own equity, loans from friends and relations and moneylenders and gifts from relations and friends. Traders rely on their colleagues, farmers or government sources such as radio and published bulletins for information on demand and supply conditions.

It was hard to estimate volumes of grains handled and traded but a conservative estimate of grains handled/traded per week was about 5000 MT in the lean season (March to August) and over 10,000 MT during the main season (September to February) [Peak period of sales is October and November]. Actual stock holding was thought to be in the hundreds of thousands of metric tons, especially during the full season. The grains are aggregated in the Dawanau from various parts of northern Nigeria as well as Niger. All the traders interviewed in Kaduna and Kano states indicated that cowpeas are imported from Niger but traders export maize, sorghum and millet to Niger. Cowpeas are purchased largely by traders from southern Nigeria for between N4,500 to N5,400 a bag of 100 kg depending on market and time of the day. Other factors influencing price fixing are prices in the previous market, demand and supply and in the current market and ability to haggle/bargain. These southern traders then sell to consumers and schools.

Regional Trade: The work of the last four years is building up an integrated picture of cowpea marketing and trade in West and Central Africa (Figure 2). The bulk of cowpea trade is between Nigeria and its neighbors. Niger alone exports about 200,000 MT annually to Nigeria. The trade to other coastal cities along the Gulf of Guinea is loosely connected to the Nigeria trade. This includes cowpea trade to Abidjan, Accra, Lome, Cotonou, Douala and Libreville. In an analogy to a watershed, grain marketers sometimes talk about a "grainshed", in which grain from outlying areas is pulled into demand centers. Using this analogy the cowpea trade among Nigeria and its neighbors might be labeled the "Nigerian cowpea grainshed."

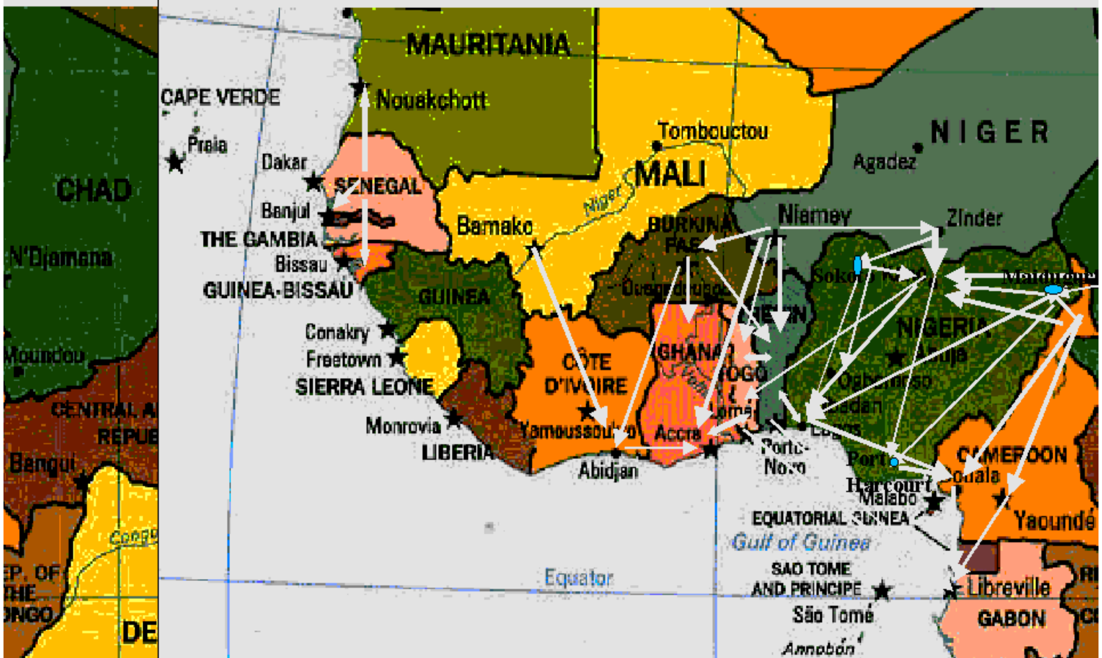
There is little linkage between the cowpea trade centered on Senegal and the rest of the West African cowpea market. Depending on supply and demand conditions in Mali and Senegal, a few bags of cowpea from one country might make their way to the other, but is not a very regular trade. In a sense, the cowpea trade among Senegal and its neighbors forms a separate "Senegalese cowpea grainshed."

Within Nigeria, the Dawanau market, Kano, handles the bulk of the cowpea bound for southern Nigeria, but some cowpea is sold directly from other northern markets, including Maiduguri and Sokoto, to southern Nigeria. While Nigeria is the largest importer of cowpeas in the world, it is also an exporter, principally to central African countries such as Gabon.

Working with CRSP collaborators in West Africa, with PRONAF scientists and with IITA researchers, a substantial amount of information on the structure of cowpea markets in both the Nigerian grainshed and the Senegalese grainshed has been collected. This includes the roles of various people involved in these markets and marketing costs. Langyintuo's dissertation will look at the marketing barriers and comparative advantage in cowpea production and transformation in the Nigerian grainshed. Faye's dissertation will consider the marketing issues in the Senegalese grainshed.

I.D.3.b.(2)(j) Current status of research: Much of the basic information on cowpea market structure and trade have been gathered. Langyintuo is working on his Ph.D. dissertation at Purdue. Musa will document the Nigerian cowpea market in his dissertation at ATBU. Faye is in the process of identifying a Ph.D. "sandwich program" in Europe or in South Africa that will allow her to meet family responsibilities while finishing her degree. The markets and trade data and analysis in this current CRSP phase lay the groundwork for collaboration with NGOs to solve marketing problems in the next phase and for a closer look at the potential for processed cowpea products in the region.

I.D.3.b.(2) Figure 2. Map of West/Central Africa Showing Identified Cowpea Trade Linkages



I.D.3.b.(2)(k) Documented impact: The initial impact of this work is on research planning. Genetic improvement, pest management and other production research now occurs with a greater understanding of where the ultimate cowpea consumers are and who they are. For instance, at the Cowpea Genetic Improvement Symposium in Dakar, January, 2001, location and characteristics of markets were key in planning a program to develop and transfer pest resistant transgenic cowpea. Effects of this research on reduction of marketing constraints will begin to be felt in the next CRSP phase.

I.D.4.b. Proposed research area work plan and subsequent annual progress report:

I.D.4.b.(1) Activity #1: Determine retail outlets, product lines and consumer awareness, purchases and utilization of cowpea-based products in Ghana.
I.D.4.b.(1)(a) Priority: (1) Essential
I.D.4.b.(1)(b) U.S. researchers: Nyankori
I.D.4.b.(1)(c) HC researchers: Sefa-Dedeh, Aniwa, Sakyi-Dawson, Gadegbeku
I.D.4.b.(1)(d) Methodology: Conduct an exit survey of a random sample of customers from a random sample of retail outlets on Wednesdays and Saturdays in Accra, Kumasi, Tamale and Ho markets to determine the type and amount of cowpea and cowpea base products being purchased; as well as awareness of and intentions to purchase other cowpea based products with emphasis on product attribute preferences.
I.D.4.b.(1)(e) Anticipated (1 year) results of activity: The nature and size of market for

cowpea and cowpea based products including information on what consumers want and are looking for in new or value-added and cowpea-based products.

I.D.4.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Increased purchases, consumption and production of value-added cowpea products and cowpea-based products in Ghana	From 2002	Retail outlets, consumer awareness, purchases, utilization and purchase intentions of cowpea and cowpea-based products

I.D.4.b.(1)(g) Budget:

UGL	$2,500
Clemson	2,500
Total (Direct costs only)	$5,000

I.D.4.b.(1)(h) Major changes: Research was refocused on food vendors and institutional buyers. The first step was to collect data for the Accra metropolitan area.

I.D.4.b.(1)(i) Progress during past year: Nyankori traveled to Ghana in August, 2001. He worked with CRSP researchers in the Department of Nutrition and Food Sciences, University of Ghana, Legon. A questionnaire was developed to collect information on cowpea suppliers, buyers, market conduct, prices and quantities in the Accra metropolitan. Data was collected from twenty food vendors and ten institutional buyers in and around Accra.

Preliminary results indicate that cowpea was readily available in a competitive market environment as evidenced by multiple supply sources and determinants of supplier choices as well as terms of trade. Furthermore, the predominance of short- term (daily or weekly) purchases suggests confidence in market prices, product quality and supply stability. Both food vendors and institutional buyers purchased most of their cowpea in produce markets, with about 70% of purchases in the market being from retailers and the remainder being from wholesalers. Only about 2.5% of purchases were directly from farmers and 2.5% from shops. Cowpea sales were concentrated on a small set of varieties (seven out of over thirty varieties grown in Ghana), and the most desirable characteristics of cowpea were those related to culinary requirements, taste as well as esthetics. Some 95% of respondents preferred cowpeas with white testa. About 60% expressed a preference for a variety labeled "Niger".

Although product utilization shows few dishes, mainly using unprocessed grains, cowpea purchases by food vendors, hospitals, and schools in the Accra metropolitan area are substantial. Some 90% of the respondents served cowpea based dishes at least once per week. A third served them daily. Based on purchases reported in the survey, it is estimated that schools, hospitals and food vendors in the metropolitan Accra area buy about 1300 MT of cowpea annually. Over 80% of that quantity is purchased by schools. A full report is being finalized.

I.D.4.b.(1)(j) Current status of research: Data collection has been completed in Cameroon and northern Ghana. A manuscript has been submitted to *Agricultural Economics* on the Cameroon and Ghana analysis. In Senegal data collection continues and a pilot effort is underway to include sucrose level and cooking time among the independent variables. In Niger data collection continues in Niamey and Maradi. One market in Zinder is being added. In Niger a pilot effort is underway with the INRAN Food Technology Department to include sucrose, cooking time and protein level in the price and quality study. The Senegalese and Nigerien pilot efforts to include biochemical characteristics in the price and quality studies lay the basis

for work in the next phase. Data collection in Nigeria was completed in Oct., 2001. The analysis will part of Shehu Musa's PhD dissertation. Data collection and analysis for Mali and CRI Ghana should be completed by the end of the current CRSP phase on April, 27, 2002.
I.D.4.b.(1)(k) Documented impact: Consumer preference information from the price and quality studies is being incorporated into cowpea breeding programs into CRSP countries and in the IITA cowpea breeding program. For example, in Senegal the breeder has started looking at the potential for developing red or speckled varieties to fit some local taste preferences.

I.E.1.b. Activity #2: Continuing training

I.E.1.b.(1) Name of student: Gloria Tetteh
Gender: Female
Nationality: Ghanaian
Degree: Ph.D.
Discipline: Food Science
Name of major professor: L. R. Beuchat
Dissertation title: Acid Tolerance Response of *Shigella flexneri* and its Implication to the Safety of Traditional Ghanaian Weaning Food
Educational institution: UGA
Date training began: August 1998
Anticipated completion date: Winter 2002
CRSP funding: Total
Budget: $16,200 (UGL)(Direct costs only)

I.E.1.b.(2) Name of Student: Mbene Faye
Gender: Female
Nationality: Senegal
Degree: Ph.D.
Discipline: Agricultural Economics
Name of Major Professor: to be determined
Thesis title: Exact title to be determined; focus on cowpea marketing in Senegal and neighboring countries
Educational Institution: to be determined
Date training began: August 1998
Anticipated completion date: December 2003
CRSP funding: Total
Budget: $22,366 (ISRA)(Direct costs only)
Status: Faye finished an M.S. degree in Ag Economics at Purdue in Dec., 2000. She was admitted to the Purdue Ag Economics Ph.D. program, but returned to Senegal because of family responsibilities. She is seeking a Ph.D. program in either Europe or South Africa that could be completed with short on-campus stays. One of the Ph.D. A sandwich program would be ideal for her case. For the next phase of the Bean/Cowpea CRSP it is proposed that her dissertation research in Senegal be funded by CRSP resources.

I.E.1.b. (3) Name of Student: Augustine Langyintuo
Gender: Male

Nationality: Ghana
Degree: Ph.D.
Discipline: Agricultural Economics
Name of Major Professor: J. Lowenberg-DeBoer
Thesis title: Spatial and Temporal Effects on Cowpea Trade in West and Central Africa
Educational Institution: Purdue University
Date training began: August 1998
Anticipated completion date: December 2002
CRSP funding: Total
Budget: $22,366 (SARI)(Direct costs only)

I.E.1.b.(4) Name of student: Abudulai Mumuni
Gender: Male
Nationality: Ghanaian
Degree: Ph.D.
Discipline: Entomology
Name of major professor: Merle Shepard
Thesis title: Impact of Natural Enemies and Botanical Materials on *Nezara viridula* in Cowpea
Educational institution: Clemson University
Date training began: January 1999
Anticipated completion date: May, 2002
CRSP funding: Total
Budget: $18,750 (SARI)(Direct costs only)
Status: Mumuni has made excellent progress on his Ph.D. program. He has published 2 papers and has 2 more ready to submit. Results of work on the impact of neem on sucking bug pests and their natural enemies will be very important in developing IPM systems for cowpea in the U.S. as well as Ghana.

I.E.1.b.(5) Name of student: Ousmane Boukar
Gender: Male
Nationality: Cameroon
Degree: Ph.D.
Discipline: Agronomy
Name of major professor: Herb Ohm
Thesis title: Genetic Analysis and Mapping of Striga Resistance in Cowpea
Educational institution: Purdue University
Date training began: January 1998
Anticipated completion date: August 2002
CRSP funding: Total
Budget: $21,142 (IRAD)(Direct costs only)
Status: Boukar has completed course requirements for his Ph.D. degree and is progressing on his thesis research. He will schedule a meeting of his advisory committee before end of November and plans to take the written prelims during the period of December 12 to December 28 and his oral prelim on January on January 3 or 4, 2002. Thus he should meet graduate school requirements so that he could complete his degree requirements in August 2002 or shortly thereafter. He plans to devote full time to DNA marker identification beginning in early January 2002 and plans to complete thesis research by August 2002.

I.E.1.b.(6) Name of student: Samba Thiaw
Gender: Male
Nationality: Senegal
Degree: Ph.D.
Discipline: Plant Physiology/Genetics
Name of major professor: A. Hall
Thesis title:
Educational institution: University of California-Riverside
Date training began: October 1998
Anticipated completion date:
CRSP funding: Total
Budget: $22,866 (ISRA) (total cost there are no indirect costs to UCR or ISRA on this item)
Status: Samba Thiaw is conducting his dissertation research at UCR and hopes to complete his Ph.D. in 2002.

I.E.1.c. Activity #3: Proposed new training

I.E.1.c.(1) Name: Nicole Sharon Komey
Gender: Female
Nationality: Ghanaian
Degree: PhD
Discipline: Food Science
Name of major professor: M.S. Chinnan
Thesis title: Process evaluation and optimization of various treatments for cooking cowpea seeds for reduced preparation time, and improved eating qualities and shelf-life.
Educational institution: University of Georgia
Date training proposed to begin: Fall of 2000
Date training anticipated to end: Summer 2003
CRSP funding: Partial
Priority: (1) Essential
Budget: $8,100 (UGL)(Direct costs only)

I.F. Constraint # 6: Insufficient Extension Services Supporting Cowpeas in the Region

I.F.1. Research area: Production, distribution of IPM storage technologies.

I.F.1.a. Background: CRSP storage technologies are already being extended in Cameroon, Senegal, Ghana, Niger, Nigeria, Burkina Faso, Mali, and Benin through PEDUNE and various NGOs. A modest effort by the CRSP can help maintain this momentum.

I.F.1.b. Proposed research area workplan and subsequent annual progress report:

I.F.1.b.(1) Activity #1: Continue to disseminate storage technology information/provide training to region.
I.F.1.b.(1)(a) Priority: (1) Essential

I.F.1.b.(1)(b) U.S. researchers: Murdock
I.F.1.b.(1)(c) HC researchers: Ntoukam, Salifu, Owusu-Akyaw, Jakpasu
I.F.1.b.(1)(d) Methodology: Distribute CRSP storage technology bulletins and training materials. Demonstrate the technologies in TOT, FFS and other training and extension settings.
I.F.1.b.(1)(e) Anticipated (1 year) results of activity: Information about CRSP storage technologies in the hands of even more farmers and extension staff.
I.F.1.b.(1)(f) Anticipated impact to which this activity will contribute, time frame and indicator:

IMPACT	TIME FRAME	INDICATOR
Lower cost storage and reduced health and environmental problems due to storage insecticide through increased public awareness of CRSP storage technologies and better trained extension staff and farmers		Greater use of CRSP storage technologies

I.F.1.b.(1)(g) Budget:

IRAD	$2,000
Total (Direct costs only)	$2,000

I.F.1.b.(1)(h) Major changes: None
I.F.1.b.(1)(i) Progress during the past year: Georges Ntoukam demonstrated the CRSP-developed storage technologies as part of the FFS he organized in the summer and fall of 2002. In addition to training 10 trainers, they were provided with the needed supplies to demonstrate the storage technologies to the groups of 5-10 women and men farmers each of them trained in their own villages in conjunction with the school.

Ntoukam developed a linkage with a Peace Corps volunteer, Stacy Charles, whose project involves benefitting low-resource women farmers in the Maroua area. Charles was given seeds of several CRSP-developed varieties or lines (Lori Niebe, CRSP Niebe, VYA, GLM 93 as well as 24-125B). She passed these seeds on to 100 female cowpea growers, and, after having been instructed by Ntoukam, instructed the women how to grow the improved varieties. The women were also instructed in the use of the post-harvest storage technologies developed by the CRSP.

Ntoukam has also worked with PNVA (National Extension system) agents based in 10 different villages in northern Cameroon; each agent in turn worked with groups of 5-10 women and men farmers in each village. These farmers were given seed of each of the improved varieties above, and instructed in appropriate cultivation methods, including the use of neem sprays. Each extension agent has also been trained in the use of the CRSP-developed storage technologies, who will train the groups of farmers in their use during the coming storage season.

Storage technologies have also begun to reach southern Africa thanks to a workshop in Harare, Zimbabwe organized by Laurie Kitch of FAO in April, 2000. Some 28 scientists and extension agents from Botswana, Mozambique, Zambia, and Zimbabwe participated. Purdue University actively supported the training by supplying training materials, including extension brochures on storage technologies. The workshop output, in the form of a 113 page booklet "Post-Harvest Storage Technologies for Cowpea (Vigna unguiculata) in Southern Africa" edited by Laurie Kitch and Tafadzwa Sibanda, has recently been published.

A. B. Salifu and others demonstrated cowpea storage technology to 178 participants of the test of pilot IPM technologies. A. B. Salifu is working with WVI to redo the storage manuals in two local languages. The local translator who was given the contract has finished the translation; the translations are being proofread prior to going to the printer. A. B. Salifu is also preparing flipchart versions under similar collaborative arrangements with WVI.
I.F.1.b.(1)(j) Current status of research: Georges Ntoukam will continue to work with PNVA extension agents and the Peace Corps volunteer through the remainder of the grant period.
I.F.1.b.(1)(k) Documented impact: None as yet. It would be extremely useful for the CRSP to commission a study of the impact of all of the efforts over the past 10 years to disseminate storage technologies.

II. ACTIVITIES DURING YEAR FROM CRSP SUPPLEMENTAL FUNDS NOT INCLUDED IN WORKPLAN

II.A. Activity #1: Convene a symposium workshop on the genetic improvement of cowpea
Background/justification: Research on the genetic improvement of cowpea, especially genetic transformation, is scattered, underfunded, and lacking coordination. All stakeholders in the effort to genetically improve cowpea will be involved.
U.S. researchers: Larry Murdock
HC researchers: various CRSPers including Ndiaga Cisse, Mbene Faye, A.B. Salifu
Methodology: Organize, convene, and report on the state of the art as regards the use of molecular techniques for the genetic improvement of cowpea; devise plans of work to address outstanding constraints, not only in cellular and molecular biology, but also policy constraints, biosafety issues, breeding, seed supply and commercialization, intellectual property matters, and public information.
Anticipated (1 year) results of activity: A successful meeting and a meeting report including a comprehensive framework and coordinated activities to foster the genetic improvement of cowpea using molecular techniques.
Anticipated impact to which this activity will contribute, time frame and indicators:.
IMPACT: Eventually the effort will lead to novel cowpea germplasm with needed insect resistance traits (especially to Maruca vitrata, but possible also Callosobruchus maculatus) not currently available.
TIME FRAME: Time frame is the next several years.
INDICATOR: Indicators will include new funding in various research/development areas essential to the area
Budget: $10,000
Progress during past year: The meeting was convened and the meeting report published.
Current status: The Dakar meeting led to the formation of NGICA: Network for the Genetic Improvement of Cowpea for Africa. Idah Sithole-Niang and Larry Murdock were chosen as Co-Chairs of NGICA. Two major grant proposals – direct outgrowths of the meeting in Dakar – have been prepared and submitted to donors. T. J. Higgins submitted a proposal to the Rockefeller Foundation for work on the genetic transformation of cowpea, while Larry Murdock, Remy Pasquet, A.B. Salifu, Joseph Huesing and Barry Pittendrigh submitted a proposal to USAID to fund work on biodiversity issues related to transgenic cowpea. Approval of both grants is pending.

II.B. Activity #2: Cowpea Genetic Improvement Plan
Background/justification: Genetic improvement of cowpea has been one of the most

successful Bean/Cowpea CRSP activities. An integrated plan was needed to prepare for the next phase proposal. In particular, the plan needed to deal with the following issues: potential incorporation of additional countries into the CRSP cowpea breeding regional activity, incorporating the growing knowledge of consumer preferences into breeding programs, and use of molecular biology tools.
U.S. researchers: Jeff Ehlers
HC researchers: Ndiaga Cisse, A.B. Salifu, Issa Drabo, Mohammed Ishiyaku, Idah Sithole-Niang, Ousmane Boukar
Methodology: The team participated in the Cowpea Genetic Improvement Symposium in Dakar, Senegal, Jan. 6-12; the West Africa Regional Meeting, Jan. 14-16, also in Dakar, and then reconvened at Purdue University, Jan. 18-23. At Purdue the team met with a variety of cowpea researchers. Based on participation in the symposium and regional meeting, and interactions with a variety of cowpea researchers in Dakar and at Purdue, a plan was developed.
Anticipated (1 year) results of activity: An integrated cowpea genetic improvement plan is developed.
Anticipated impact to which this activity will contribute, time frame and indicators:
IMPACT: Cowpea varieties that better fit consumer preferences are developed more quickly.
TIME FRAME: Five years
INDICATOR: New CRSP cowpea varieties adopted widely in West Africa
Budget: $35,000
Progress during past year: The cowpea improvement team participated in the Cowpea Genetic Improvement Symposium and Regional Meeting as planned. They met a Purdue with: Ralph Waniska, Texas A&M, Food Science; William Payne, Texas A&M, Agronomy, Larry Murdock and Richard Shade, Purdue, Entomology; Ray Bressan, Purdue, molecular biologist; Augustine Langyintuo, Purdue, Ag. Economics; and others. They completed a report and entitled: Cisse, N, A.B. Salifu, I. Drabo, M. Ishiyaku, I. Sithole-Niang, O. Boukar and J. Ehlers, Cowpea Genetic Improvement- The Next Five Years and Beyond.

This report outlines the continuing need for conventional breeding to provide varieties that have resistance to multiple pests, and adapt to drought and low soil fertility. It highlights the need to breed for characteristics demanded by specific consumer markets. The report emphasizes the need for a multidisciplinary team approach that includes entomologists, plant pathologists, nematologists, plant physiologists, and economists. Input from cowpea growers should be sought in both West Africa and the U.S. It also indicates the need to incorporate new scientific tools, such as use of molecular markers.
Current status: Completed

II.C. Activity #3: West Africa Regional Meeting, 2001
Background/justification: An annual face-to-face meeting is essential to planning CRSP cowpea research for West Africa. If possible the meeting is held in conjunction with a conference or some other event to reduce travel costs. Previous meetings include: 2000, East Lansing, MI, USA, in conjunction with the CRSP All Researchers Conference; 1999, Cotonou, Benin, in conjunction with the PRONAF annual meeting; and 1997, Dakar, Senegal.
U.S. researchers: Research Advisors: Larry Murdock, Dick Phillips, Jeff Ehlers (representing Tony Hall), J. Lowenberg-DeBoer; Management Office Representative: Mywish Meridia.
HC researchers: Research Advisors: A.B. Salifu, Mbene Faye, Ndiaga Cisse, Esther Sakyi-Dawson (representing Sam Sefa-Dedah), and visitors: Johnson Olufowote, World Vision; Mamadou Balde, ISRA, Senegal; Issa Drabo, INERA, Burkina Faso; Mohammed Ishiyaku, IAR,

Nigeria; and Idah Sithole-Niang, University of Zimbabwe.
Methodology: A quick overview was conducted of research results since the last meeting in April, 2000, reports from the CRSP Management Office, and the technology transfer INTERCRSP. Research area groups met to develop draft workplans for the final seven months of the current phase. The group met in plenary session to discuss proposed activities and budgets.
Anticipated (1 year) results of activity: workplan for the period 1 Oct., 2001 to 27 April, 2002, plus planning for the next five year phase.
Anticipated impact to which this activity will contribute, time frame and indicators:
IMPACT: greater cowpea production and utilization in West Africa and in the US
TIME FRAME: Five years
INDICATOR: Widespread adoption of: cowpea varieties developed with CRSP participation, integrated pest management techniques developed and disseminated by the CRSP, non-chemical cowpea storage technologies, cowpea food technology and cowpea marketing solutions.
Budget: $16,650
Progress during past year: The 2001 West Africa Regional meeting was help in Dakar, Jan. 14-17 in conjunction with the Cowpea Genetic Improvement Symposium. A.B. Salifu presided. The cowpea genetic improvement team participated in the discussion as non-voting observers. A workplan was developed and minutes are available.
Current status: 2001 meeting completed. Meeting planned for early 2002.

III. EVALUATION OF FUNDING/FISCAL MANAGEMENT IN FY 2001

III.A. Constraints Related to Level of, Delay in Receiving, or Reporting of CRSP Funds:

Sénégal/UCR: The delay in receiving funds from USAID in 2001 was totally unacceptable. The Management Office at MSU did not provide this project with funds for the period April 16, 2001 through September 30, 2001 until after the period was ended. We received a letter from the Management Office saying the funds were coming only on August 30, 2001. The fault was with USAID not MSU. The project was able to continue operating because the administration at UCR had faith that the funds would eventually arrive but this is not good enough.

As in the past, the delay in April allocation of funds continued to cause critical problems especially with out subcontracts.

The most critical issue was that we could not extend the subcontracts with the host country (IRAD/Cameroon) beyond April 27, and funds could not be transferred to cover the costs of initiating the planting season. This created a major research problem and affected the ongoing research. The Cameroon team was at a critical time–that of planting the cowpea crop, and yet had not funds available. Had the funds not reached them at the last minute, the entire growing season would have been lost.

At Purdue, the contract office initiated a “Notice to Proceed” to allow our program to expend funds on campus beyond the expiration date. But we could not allocate additional funds to the subcontract in Cameroon until the official amendment came from Michigan State.

Purdue’s fiscal office is also requesting a change in the billing frequency. The AID Management Review team was informed by the Management Office that we could bill the Bean/Cowpea MO on a monthly basis but our contract states that we can only submit quarterly invoices. Purdue is requesting clarification.

UGA: The delay in receiving the "April" funding until nearly September necessitated a scramble to find temporary sources of assistantship and operating funds until it was finally received and processed. While this was in no way the fault of the ME, it nevertheless caused hardship and disruption for the project. This situation makes it impossible to expend the April-September funds before the end of the FY. In addition, personnel turnover at UGA from the Department to the Research Foundation levels caused confusion and delays in processing financial transactions. These together, will necessitate a bit of leeway from the ME in tidying up the end of the year financial situation and carry over of funds.

III.B. Leveraged Funds:

For the Dakar Cowpea Meeting
Rockefeller Foundation — $40,000
Anonymous Donor — $23,000
Contributions in kind (covering travel costs of participants)
By FAO, IITA

As part of the InterCRSP East Group project entitled, "Restoration and Maintenance of Degraded Range and Farmlands for Increased Productivity in the Sudano-Sahelian Zones of West and Central Africa, Purdue received $36,295 in the 2000-2001 fiscal year. A key activity has been the economic evaluation of potential leguminous cover crops, including mucuna pruriens and cowpea. The key hypothesis is that under current price conditions farmers prefer cowpea because it provides a marketable grain, as well as forage. Mucuna might be preferred when grain sorghum and/or livestock prices are high relative to cowpea grain prices.

In January and February, 2001, Nadine Adouyam collected data on forage production and use in the village of Kwara Gohe, Niger. Adouyam is working on her Master of Science degree under Lowenberg-DeBoer in the Purdue Agricultural Economics Department. Her work in Niger was supervised by Germaine Ibro, INRAN/DECOR. Kwara Gohe is in the Gaya area of southwestern Niger, near the InterCRSP site at Tanda. With the data, Adouyam is modifying a representative farm linear programming model for the Gaya area to include forage and livestock production. She expects to be finished in early 2002.

III.C. Other Funds:

UCR: UCR received grants providing $15,500 and $15,000 direct cost funding from the California Dry Bean Advisory Board for research on "Blackeye Varietal Improvement" during the years 2000 and 2001, respectively.

UGA: Students and technical staff supported on other funds make regular contributions to this CRSP project but given the team approach we employ to our research, this is difficult to quantify.

IV. PUBLICATIONS, PRESENTATIONS AND AWARDS IN FY 2001

IV.A. Refereed Publications:

Abudulai, M. and B. M. Shepard. 2001. Timing Insecticide Sprays for Control of Pod-Sucking Bugs (Pentatomidae, Coreidae and Alydidae) in Cowpea (*Vigna unguiculata* [L.] Walpers). Journal of Agricultural and Urban Entomology 18:51-60.

Abudulai, M., B. M. Shepard and P. L. Mitchell. 2001. Parasitism and Predation on Eggs of *Leptoglossus phyllopus* (L.) (Hemiptera: Coreidae) in Cowpea: Impact of Endosulfan Sprays. Journal of Agricultural and Urban Entomology (accepted).

Fery, R. L. 2001. Notice of Release of "Charleston Nemagreen," a Root-Knot Nematode Resistant Cream-Type Southernpea with a Green Cotyledon Phenotype. U.S. Department of Agriculture, August 1.

________ 2001. Notice of Release of "DoubleGreen Delight," a Cream-Type Southernpea with an Enhanced Persistent Green Seed Phenotype. U.S. Department of Agriculture, August 1.

Kerr, W. L., C. D. W. Ward, K. H. McWatters and A. V. A. Resurreccion. 2001. Milling Particle Size of Cowpea Flour and Snack Chip Quality. Food Resources International 34:39-45.

Kitch, L. W., J. Ehlers, O. Boukar, G. Ntoukam and L. L. Murdock. Registration of C93W-24-125B Cowpea Germplasm. Crop Science (submitted).

McWatters, K. H., C. -Y. -T. Hung, Y. -C. Hung, M. S. Chinnan and R. D. Phillips. 2001. Akara Making Characteristics of Five U.S. Varieties of Cowpeas (*Vigna unguiculata*). Journal of Food Quality 24:53-65.

Mensa-Wilmot, Y., R. D. Phillips and J. L. Hargrove. 2001. Protein Quality Evaluation of Cowpea-Based Extrusion Cooked Cereal/Legume Weaning Mixtures. Nutrition Resources 21:849-857.

Mensa-Wilmot, Y., R. D. Phillips and S. Sefa-Dedeh. 2001. Acceptability of Extrusion Cooked Cereal/Legume Weaning Food Supplements to Ghanaian Mothers. Food Resources International 52:83-90.

Shepard, B. M., E. F. Shepard, G. R. Carner, M. D. Hammig, A. Rauf and S. G. Turnipseed. 2001. Integrated Pest Management Reduces Pesticides and Production Costs of Vegetables and Soybean in Indonesia: Field Studies with Local Farmers. Journal of Agromedicine 7:31-66.

Tetteh, G. L. and L. R. Beuchat. 2001. Sensitivity of Acid-Adapted and Acid-Shocked *Shigella flexneri* to Reduced pH Achieved and Acetic, Lactic and Propionic Acids. Journal of Food Protocols 64:975-981.

IV.B. Non-Refereed Publications:

Abudulai, M., B. M. Shepard and P. L. Mitchell. 2001. Antifeedant Effects and Toxicity of Neem (Neemix 4.5 EC) to the Southern Green Stink Bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae). Poster presentation at the Fifth Joint Meeting of the Georgia and South Carolina Entomological Societies, Gainesville, GA, April 4-6.

Fang, C. 2000. Finite Element Modeling of Physiochemical Changes During Steaming of Cowpea Seeds. M.S. Thesis, University of Georgia, p. 110.

IV.C. Presentations:

Adouayom, N. and J. Lowenberg-DeBoer. 2001. Evaluation of the Potential for Adoption of Mucuna as a Cover Crop by Farmers in the Gaya Area. InterCRSP Annual Meeting, Niamey, Niger, February.

Coulibaly, O. and J. Lowenberg-DeBoer. 2001. The Economics of Cowpea in West Africa. Symposium/Workshop on the Genetic Improvement of Cowpea, Dakar, Sénégal, January.

Fang, C., M. S. Chinnan and R. D. Phillips. 2001. Gelatinization During Steaming of Intact Cowpea Seeds. Annual Meeting of the Institute of Food Technologists, New Orleans, LA, June 23-27, p. 44. (Abstract)

Faye, M. 2001. Commercialization of Cowpea in Sénégal, Preliminary Results. Seminar, ISRA, Bambey, Sénégal, August 7.

Lanygintuo, A. and W. Dogbe. 2000. Ex-ante Analysis of the Adoption of a Callopogonium mucunoides Improved Fallow in Rice Production Systems in Northern Ghana. Presented at the American Society of Agronomy (ASA) Annual Meeting, November.

Lowenberg-DeBoer, J. 2001. Overview of Bean/Cowpea CRSP Socio-Economics Studies. Review and Planning Workshop, Cowpea Project for Africa (PRONAF), Cotonou, Benin, May.

McWatters, K .H., J. B. Ouedraogo, A. V. A. Resurreccion, Y. -C. Hung and R. D. Phillips. 2001. Physical and Sensory Characteristics of Sugar Cookies Containing Mixtures of Wheat, Fonio and Cowpea Flours. 2001 Annual Meeting, Institute of Food Technologists, New Orleans, LA, June 23-27, Book of Abstracts, p. 101.

Murdock, L. L. 2001. An Entomologist's Cowpea Adventures in Africa. Invited lecture, Kansas State University, KS, March.

Patterson, S. P., K. H. McWatters, Y. -C. Hung, M. S. Chinnan and R. D. Phillips. 2001. Consumer Acceptability of Akara (Fried Cowpea Paste) Made From Three Different Varieties of Cowpeas. 2001 Annual Meeting, Institute of Food Technologists, New Orleans, LA, June 23-27, Book of Abstracts, p. 252.

Salifu, A. B., B. M. Shepard, M. Owusu-Akyaw, J. V. K. Afun, M. Abudulai. 2000. Managing Insect Pests of Cowpea in the Field; Farmer Field Schools. Proceedings of Bean/Cowpea CRSP Midcourse Researchers Meeting, East Lansing, MI, April.

Tetteh, G. L. and L. R. Beuchat. 2001. Sensitivity of Acid-Adapted and Acid-Shocked *Shigella flexneri* to Reduced pH Achieved with Acetic Lactic and Propionic Acids. Abstract of poster presentations, 8th Annual Meeting, CFS, Atlanta, GA, March 6-7, p. 8-9.

IV.D. Awards and Recognitions:

Murdock, L. L. 2001. Kansas State University Entomology Department Distinguished Alumnus Award.

Shepard, B. M. 2001. Best Research Paper Award. Presented to the Joint Georgia/South Carolina Entomology Societies Meeting, Gainesville, GA, April 3-4.

V. IDEAS FOR STRENGTHENING PROJECT

UCR: The current annual reports are not particularly useful. They are designed to help the External Evaluation Panel. Project scientists and other people do not find them interesting. The system of reporting should be changed to make it easier for project scientists to do. Also, project reports should be designed so that they are more interesting to a broader range of people.

UGA: The research team of this project were relieved when the concept of decentralized funds management was not adopted as we felt that there were numerous disadvantages in addition to the additional costs. We appreciate the enthusiastic and professional operation of the MO who manage to keep on top of so many details with a small staff. We applaud the idea of more electronic reporting and, in fact, meeting whenever possible to save time and money.

V. IDEAS FOR STRENGTHENING PROJECT

PURDUE: A recommendation for the Bean/Cowpea CRSP would be to undertake a comprehensive evaluation of the adoption and impact of its technologies and training. This review and evaluation should encompass (1) storage IPM technologies (2) field IPM technologies (3) food science-related technologies and (4) CRSP-developed cultivars. The review should be conducted by an impartial third-party organization. I suggest this because I believe the CRSP has inadequately evaluated our impact in Africa and Latin America, and I also believe that the CRSP will discover that is impact has been far greater than one might anticipate.

The CRSP would benefit greatly if the annual reporting were greatly simplified. Equally important, the annual report should be due at a different date than heretofore. Instead of a November 1 deadline, the deadline should be March 1 or April 1. The November 1 deadline is the worst possible time, for many reasons. Virtually all other reports at Purdue US are due in October and November. October, for many of us, becomes crisis time, perennially. A March (or April) deadline would give researchers time to fully analyze the results of the previous year's work and concomitantly plan for the next year. For many of us, the November 1 deadline comes exactly in the middle of the harvest season. This makes it impossible to collect and analyze the data of the immediately previous growing season, and report on it on time. The result is that we are left to report the results of the previous year's work, nearly one year late! By that time our minds are occupied with the current year's results, which are being collected and analyzed. This makes report writing confusing, and much less effective. There would appear to be no insurmountable barrier to changing the reporting date: INTSORMIL's annual reports are due August 1.